CALIFORNIA ENERGY COMMISSION

Small HVAC Field and Survey Information

Summary of Background Research Results (product 4.3.1)

Description of the Field Methods (product 4.4.1)

Survey Method and Questionnaires:
- Small HVAC Onsite Survey Form (product 4.4.2)
- Functional Performance Test (product 4.4.2)
- Economizer Survey (product 4.4.2)
- Spot Power Measurement (product 4.4.2)
- KW Survey (product 4.4.2)

(This item is located in the *Additional Documents* file)

TECHNICAL REPORT

October 2003
500-03-082-A-23

Gray Davis, *Governor*

CALIFORNIA ENERGY COMMISSION

Prepared By:
Architectural Energy Corporation
Pete Jacobs, Lead Author
Boulder, Colorado

Managed By:
New Buildings Institute
Cathy Higgins, ***Program Director***
White Salmon, Washington
CEC Contract No. 400-99-013

Prepared For:
Donald Aumann,
Contract Manager

Nancy Jenkins,
PIER Buildings Program Manager

Terry Surles,
PIER Program Director

Robert L. Therkelsen
Executive Director

ACKNOWLEDGEMENTS

The products and outcomes presented in this report are part of the **Integrated Design of Small Commercial HVAC Systems** research project. The reports are a result of funding provided by the California Energy Commission's Public Interest Energy Research (PIER) program on behalf of the citizens of California. Architectural Energy Corporation would like to acknowledge the support and contributions of the individuals below:

Program and Contract Management: Cathy Higgins, New Buildings Institute; Don Aumann, California Energy Commission.

Technical Advisory Group (TAG): Tudi Hassl of Portland Energy Conservation, Inc. (PECI), Jan Johnson of Southern California Edison, John Proctor of Proctor Engineering Group, Richard Lord of Carrier Corporation, Dr. Mark Modera of Carrier Aeroseal.

Architectural Energy Corporation Project Team: Pete Jacobs led the project, with AEC staff support from Dave Roberts, Tracy Phillips, Erik Jeanette, John Wood, Matthew Potts, Kosol Kiatreungwattana, Pablo Calderon-Rodriguez and Judie Porter. RLW Analytics as a subcontractor provided field testing and engineering support and statistical analysis, including contributions from Roger Wright, Matt Brost, Jeff Staller, Eric Swan, Amber Watkins and Stacia Okura. Eskinder Berhanu, Principal of Eskinder Berhanu Associates also provided field testing and engineering support.

Additional Support: Alan Cowan and Jeff Johnson of New Buildings Institute, project technical review and Design Guide review; Darren Goody of PECI, Design Guide Review.

PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

This document is one of 33 technical attachments to the final report of a larger research effort called *Integrated Energy Systems: Productivity and Building Science Program* (Program) as part of the PIER Program funded by the California Energy Commission (Commission) and managed by the New Buildings Institute.

As the name suggests, it is not individual building components, equipment, or materials that optimize energy efficiency. Instead, energy efficiency is improved through the integrated design, construction, and operation of building systems. The *Integrated Energy Systems: Productivity and Building Science Program* research addressed six areas:

- Productivity and Interior Environments
- Integrated Design of Large Commercial HVAC Systems
- Integrated Design of Small Commercial HVAC Systems
- Integrated Design of Commercial Building Ceiling Systems
- Integrated Design of Residential Ducting & Air Flow Systems
- Outdoor Lighting Baseline Assessment

The Program's final report (Commission publication #P500-03-082) and its attachments are intended to provide a complete record of the objectives, methods, findings and accomplishments of the *Integrated Energy Systems: Productivity and Building Science Program*. The final report and attachments are highly applicable to architects, designers, contractors, building owners and operators, manufacturers, researchers, and the energy efficiency community.

This attachment, "Small HVAC Field and Survey Information" (Attachment A-23), provides supplemental information to the program's final report within the **Integrated Design of Small Commercial HVAC Systems** research area and includes the following reports:

1. **Summary of Background Research Results.** An overview of background research conducted in areas relevant to improving the installed efficiency of small HVAC systems through improved systems integration.

2. **Description of the Field Methods.** A PowerPoint document used to train the people who would be conducting field surveys of small package HVAC units in California commercial buildings.

3. **Survey Method and Questionnaires.** A series of forms and test protocols used by the project's field staff when conducting site surveys of buildings with small package HVAC units. Includes an onsite survey form used when interviewing the building representative about occupancy history, schedule and other unobservable information; functional performance test protocol and procedures; economizer survey form used to record data about the site's HVAC units; spot power measurement procedure; and kW survey form used to record the units' kW measurements.

The Buildings Program Area within the Public Interest Energy Research (PIER) Program produced these documents as part of a multi-project programmatic contract (#400-99-413). The Buildings Program includes new and existing buildings in both the residential and the non-residential sectors. The program seeks to decrease building energy use through research that will develop or improve energy efficient technologies, strategies, tools, and building performance evaluation methods.

For other reports produced within this contract or to obtain more information on the PIER Program, please visit www.energy.ca.gov/pier/buildings or contact the Commission's Publications Unit at 916-654-5200. All reports, guidelines and attachments are also publicly available at www.newbuildings.org/pier.

ABSTRACT

The "Small HVAC Field and Survey Information" consists of three reports produced as a part of the Integrated Design of Small Commercial HVAC Systems project, one of six research elements in the *Integrated Energy Systems: Productivity and Building Science* Program. This program was funded by the California Energy Commission's Public Interest Energy Research (PIER) Program.

This project conducted field surveys and short-term monitoring of packaged HVAC systems up to 10 tons per unit and identified problems that lead to poor system performance. This attachment consists of documents developed as part of the project's early research tasks.

1. **Summary of Background Research Results.** An overview of background research conducted in areas relevant to improving the installed efficiency of small HVAC systems through improved systems integration.

2. **Description of the Field Methods.** A PowerPoint document used to train the people who conducted the field surveys of small package HVAC units in California commercial buildings.

3. **Survey Method and Questionnaires.** A series of forms and test protocols used by the project's field staff when conducting site.

   - *Small HVAC Onsite Survey Form.* Interview questions used to identify occupancy history, schedules and other unobservable aspects of the buildings.
   - *Functional Performance Test.* An outline of procedures used for testing the units' performance.
   - *Economizer Survey.* A form for recording data about the HVAC units and economizers.
   - *Spot Power Measurement.* An outline of the spot measurement procedure utilizing two techniques: phase-to-neutral and phase-to-phase.
   - *KW Survey.* A form for recording the units' kW measurements.

Author: Pete Jacobs, Architectural Energy Corp.

Keywords: packaged HVAC system, economizer, spot power measurement, RTU, thermostat, damper, DX air conditioner, refrigerant charge

Integrated Energy Systems Productivity & Building Science Program

A project of the State of California PIER Program

Element Four – Integrated Design of Small Commercial HVAC Systems

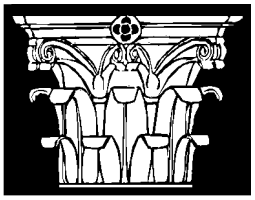
Background Research Summary

Final August 15, 2002

Deliverable Number 4D4.3.1

PIER
Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

ARCHITECTURAL ENERGY CORPORATION
Integrated Engineered Solutions



INTRODUCTION

The purpose of the background research task is to develop research questions pertaining to small commercial HVAC systems. Background research was conducted in areas relevant to improving the installed efficiency of small HVAC systems through improved systems integration. The background research activities fall into two general categories:

1. Market characterization, which is intended to gather information to better understand the demographics of the buildings with small HVAC systems, and understand the market penetration of various types of small HVAC systems
2. Systems integration, which is intended to identify prior and future studies relating to systems integration issues in small HVAC systems.

MARKET CHARACTERIZATION

The focus of Element 4 is small HVAC systems in new non-residential buildings in the State of California. The primary data resource for the market characterization study is the California Statewide Non-Residential New Construction (NRNC) database. This database was used to develop market characterization data relevant to this project.

NRNC Database

The California NRNC database is a collection of 990 buildings statistically selected to represent the majority of statewide NRNC activity. The majority of the data come from about 880 on-site surveys conducted during impact evaluation studies of the SCE and PG&E 1994 and 1996 NRNC energy efficiency programs. These data were supplemented with thirty audits from the impact evaluation of the 1995 SDG&E NRNC program and additional on-site surveys designed to supplement the existing data. Participants in utility energy-efficiency programs are included, but are weighted according to their general representation in the population. The population was defined using a listing of new construction projects obtained from F. W. Dodge. The Dodge database seeks to list all new construction projects that are valued over $200,000 and are expected to start within 60 days. The data include renovations and expansions as well as entirely new buildings.[1] These data were filtered to exclude projects not covered under Title 24. The population-weighted square footage distribution of audited sites in the NRNC database is shown by building type in Figure 1. These data are compared to estimates of new construction activity in 2001 supplied by the CEC.

[1] The data is thought to cover over 95% of all projects that are competitively bid.

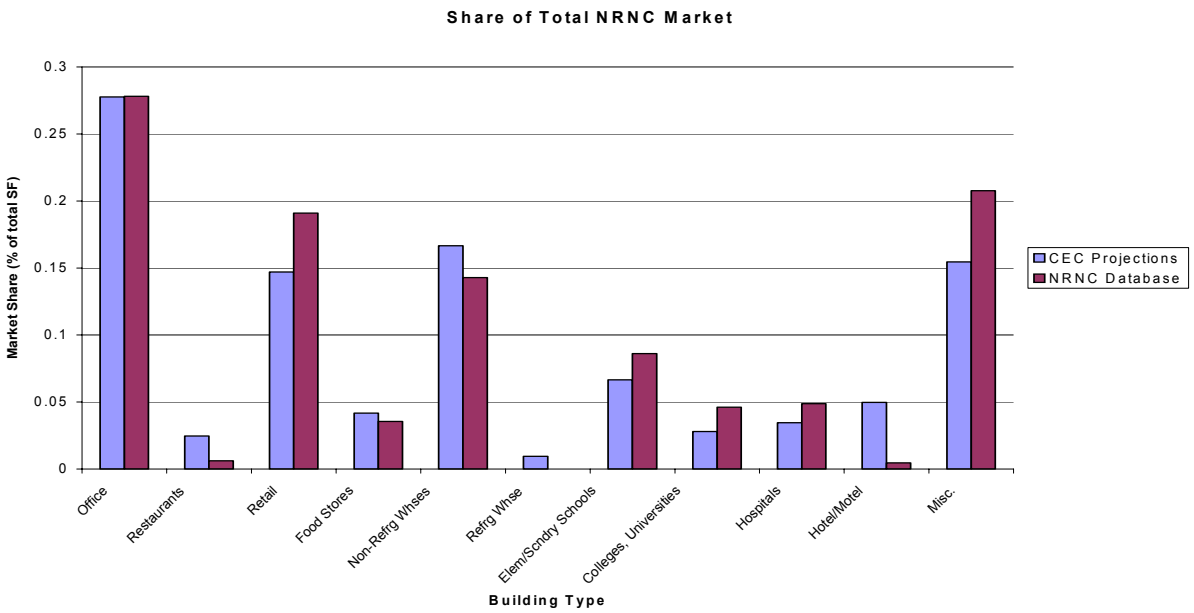


Figure 1 – Estimates of NRNC Construction Activity by Building Type

Note, the market share distribution in the NRNC database and the CEC projections are fairly close in most important market categories. Notable exceptions are the Restaurant and Hotel/Motel sectors, which generally do not comprise a large fraction of the total NRNC activity.

During the audits, information on building physical characteristics such as types of lighting and plug load inventories, types and efficiency of HVAC equipment, insulation levels, and glazing properties were collected. Building occupants were interviewed to determine behavior characteristics such as occupancy schedules and equipment operation. The on-site data were used to develop DOE-2 building energy simulation models through an automated modeling process. Most building simulation models were calibrated to monthly billing data when the data were available.

The NRNC data represent the broad range of construction practices, climate zones and occupant behavior expected in a building population as diverse as the NRNC market. For example, the office segment contains a wide variety of buildings ranging from glass and steel skyscrapers to one-story wood frame buildings. Each site in the sample has a statistically derived sample weight and precision, expressing the relative representation of each building in the NRNC population, thus allowing the results obtained from simulations of each individual building to be projected to the population with a quantifiable level of precision.

Common Types of HVAC Systems

The distribution HVAC system types present in NRNC by floor area served is shown in Figure 2 below:

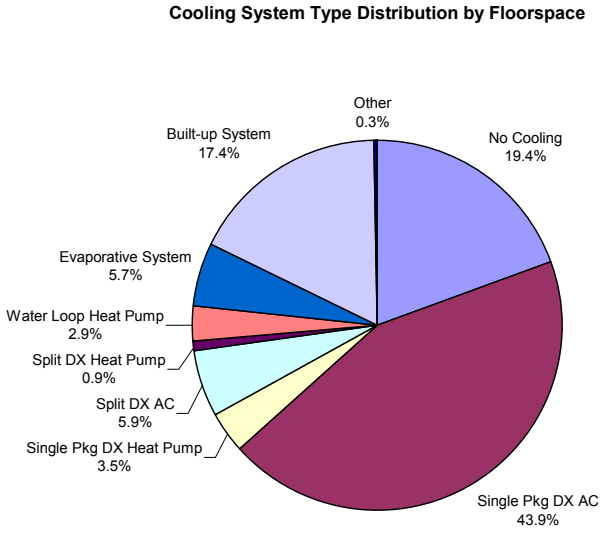


Figure 2. Floorspace Distribution of HVAC Systems in Commercial Buildings

Note that single package DX air conditioners are the most popular HVAC system type in new construction in the state, cooling about 44% of the total floorspace. Built-up systems are the second-most popular, conditioning about 17% of the total floorspace. The combined total of single package and split DX air conditioners and heat pumps represents slightly more than half of the total floorspace in the state. Note that a significant portion (about 19%) of the total NRNC floorspace is not cooled.

Packaged DX systems are further classified by whether they serve a single zone or multiple zones. Single zone constant volume systems are most popular, with a few packaged DX systems utilizing variable air volume (VAV) or variable volume and temperature (VVT) controls to serve multiple zones. The distribution of constant volume, VAV, and VVT systems by quantity and installed cooling capacity is shown in Figures 3 and 4.

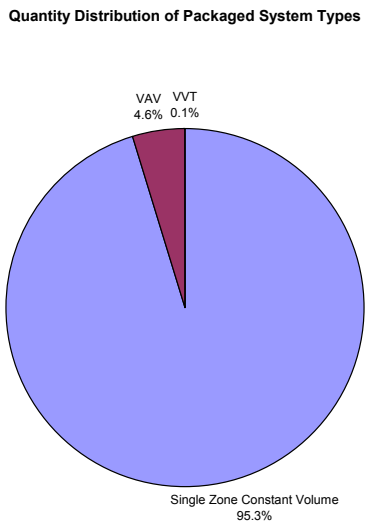


Figure 3. Quantity Distribution of Packaged DX HVAC System Types (Single zone, Multiple zones)

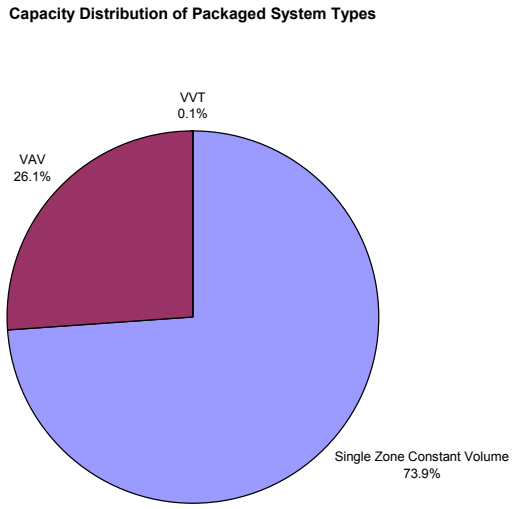


Figure 4. Capacity Distribution of Packaged DX HVAC System Types (Single zone, Multiple zones)

The market penetration of the various types of single zone constant volume packaged DX air conditioners and heat pumps is shown in Figures 5 and 6. In Figure 5, the market penetration is expressed in terms of number of systems. In Figure 6, the market penetration is expressed in terms of installed cooling capacity.

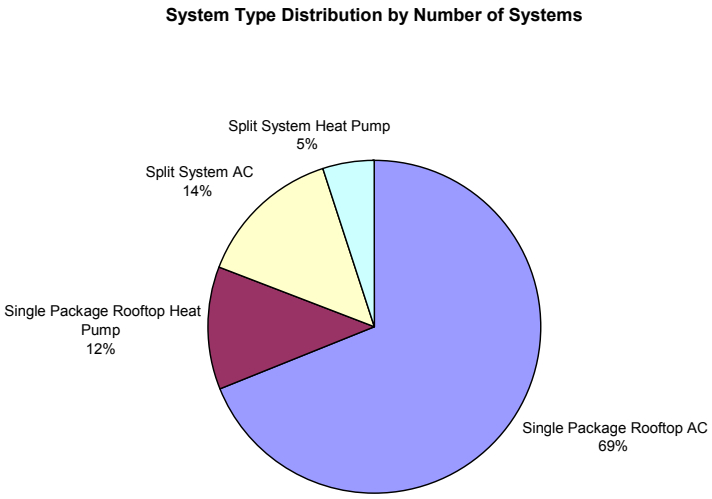


Figure 5. Distribution of DX System Types by Number of Systems

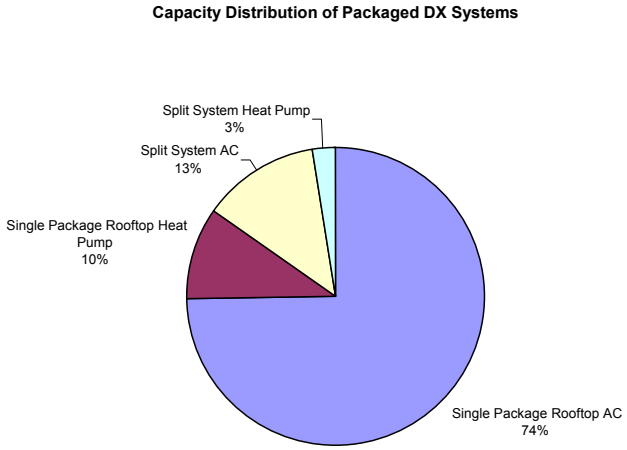


Figure 6. Distribution of DX System Types by Installed Capacity

These charts illustrate the single package equipment is the most popular packaged DX system type in new commercial buildings. Split systems and heat pumps, although present, do not represent a large fraction of the number of systems or installed cooling capacity.

The size distribution of packaged DX systems is shown in Figures 7 and 8. Again, the figures show the distributions in terms of number of systems and installed cooling capacity.

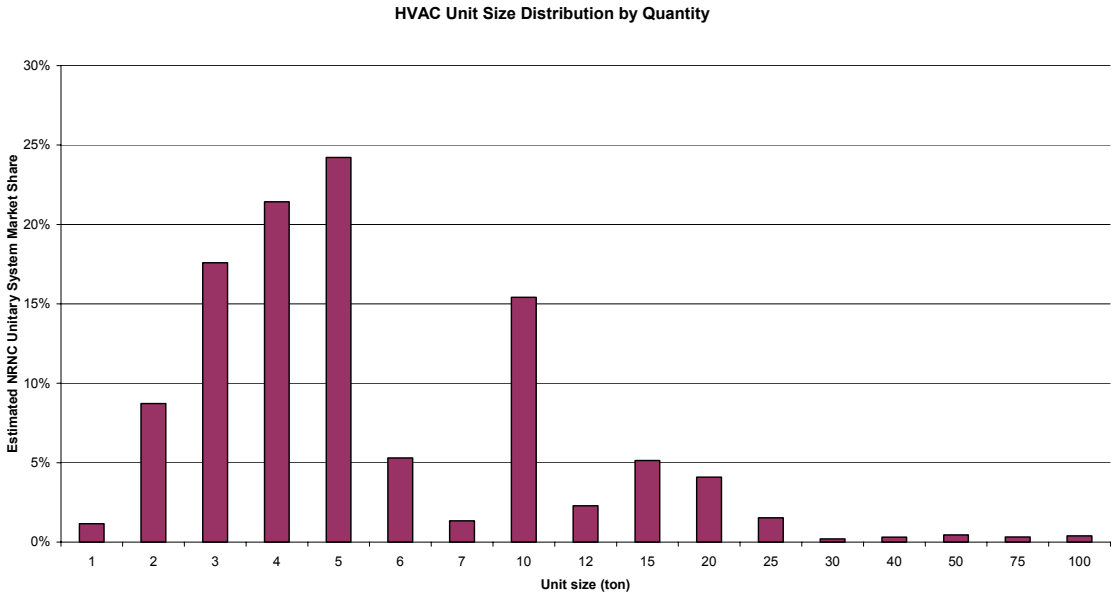


Figure 7. Distribution of Packaged DX System Size by Number of Systems

In terms of number of systems installed, the most popular packaged DX system size is 5 tons. Units between 1 and 10 tons represent close to 90% of the total unit sales in new buildings in California.

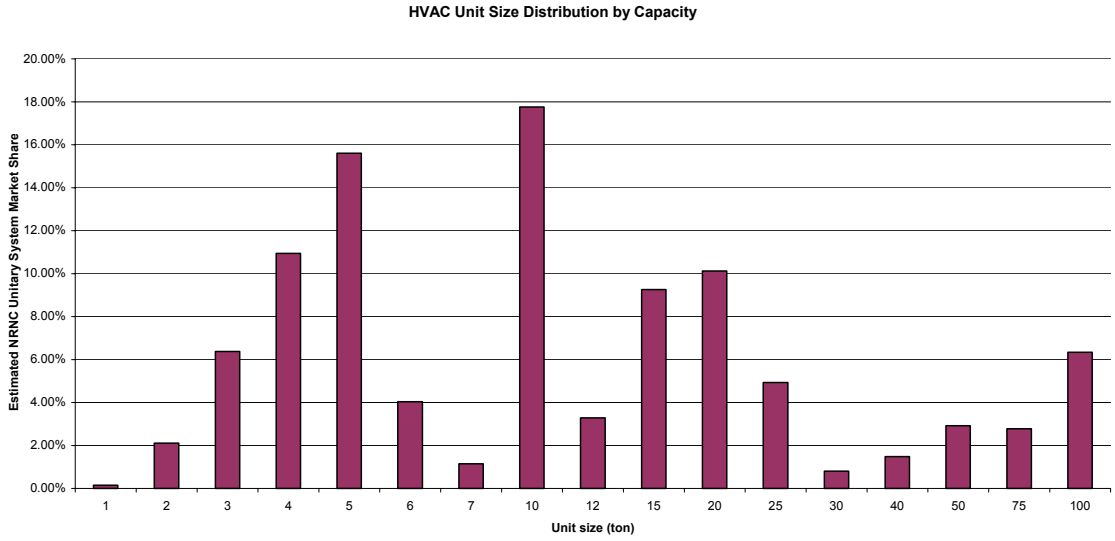


Figure 8. Distribution of Packaged DX System Size by Installed Capacity

Figure 8 tells a slighting different story. The 10 ton unit is the most popular, in terms of installed cooling capacity, followed by the 5 ton unit. The cumulative distribution of packaged DX system capacity by size is shown in Figure 9.

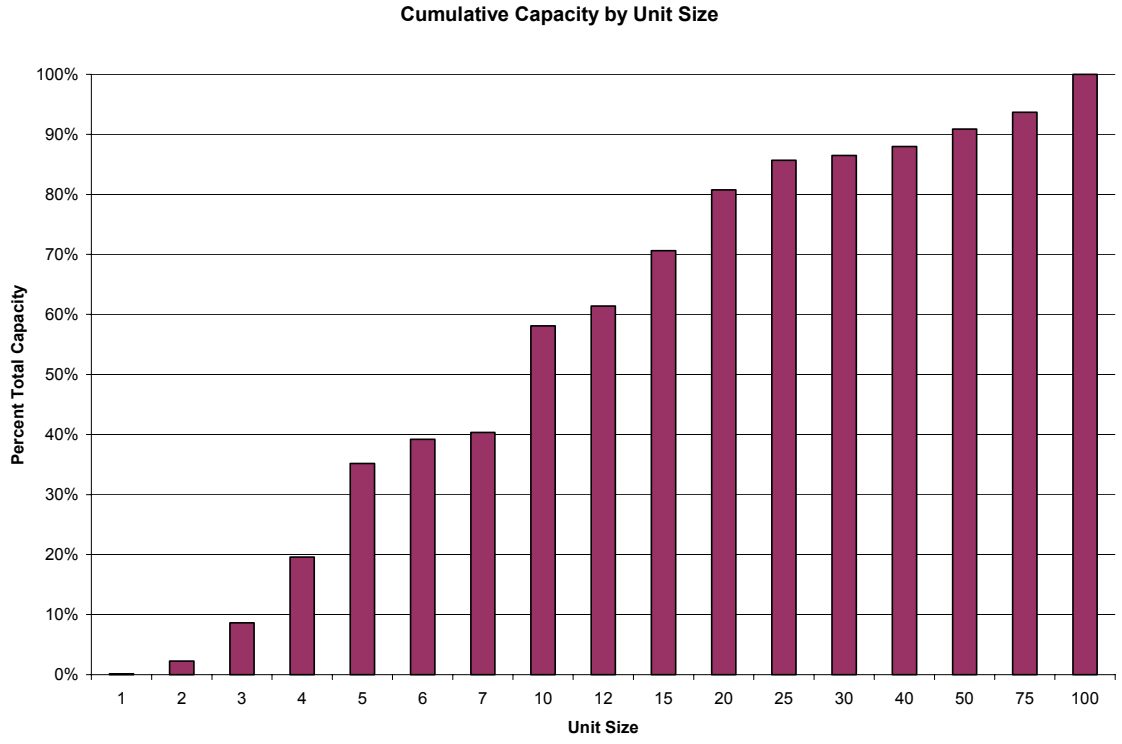


Figure 9. Cumulative Distribution of Packaged DX System Size by Installed Capacity

Note that units 10 tons and smaller represent about 58% of the total packaged DX cooling capacity in the state.

Buildings with Small HVAC Systems

The NRNC database was queried to develop an understanding of the types and sizes of buildings using small HVAC systems, defined here as units 10 tons and smaller, and the number of units installed per building. Table 1 describes the penetration of small systems by building type, and the average number of systems per building on buildings that have small systems. The business types occupying these buildings (based on the three digit Standard Industrial Classification (SIC) code) is also shown. See Appendix B for a description of the business types represented by the three digit SIC code.

Table 1. Buildings with Small HVAC Systems

CEC Building Type	SIC codes represented	Have at least one small unit	Average Units/building (buildings with at least one small system)
Colleges, Universities	822	34.0%	1.6
Elem/Scndry Schools	821, 824	72.7%	11.9
Food Stores	514	74.0%	2.6
Hospitals	806	51.9%	2.4
Hotel/Motel	701	56.2%	2.3
Large Office	162, 274, 291, 357, 367, 421, 431, 481, 481, 489, 511, 516, 602, 606, 614, 621, 632, 633, 637, 639, 641, 653, 672, 737, 737, 781, 806, 872, 873, 874, 919, 921, 922, 941, 971	53.9%	2.5
Large Retail	513, 521, 531, 566, 571, 573, 599	92.5%	7.0
Medical Clinic	801, 802	49.6%	2.0
Misc.	131, 201, 202, 203, 205, 208, 225, 242, 244, 251, 274, 283, 323, 335, 341, 344, 349, 354, 355, 356, 357, 362, 364, 365, 367, 369, 371, 384, 393, 399, 401, 431, 489, 495, 526, 721, 726, 731, 733, 737, 751, 753, 754, 781, 783, 792, 794, 799, 807, 821, 823, 832, 833, 835, 836, 841, 864, 866, 873, 919, 922, 953, 962, 964, 971	74.0%	4.0
Non-Refrg Whses	201, 203, 205, 208, 209, 227, 238, 242, 243, 265, 274, 308, 331, 353, 357, 359, 382, 421, 422, 504, 511, 581, 599, 861, 871, 919	71.4%	2.8
Restaurant	581	83.8%	3.2
Small Office	176, 203, 208, 209, 242, 267, 272, 273, 283, 289, 339, 349, 355, 357, 364, 366, 367, 371, 376, 384, 421, 431, 449, 458, 481, 484, 489, 494, 495, 513, 516, 527, 602, 603, 606, 614, 621, 639, 641, 653, 673, 733, 737, 781, 832, 839, 861, 863, 866, 869, 871, 873, 899, 919, 921, 922, 941, 944, 962, 964	78.4%	6.2
Small Retail	501, 502, 504, 512, 513, 521, 525, 526, 565, 531, 533, 539, 554, 551, 564, 565, 566, 571, 573, 581, 592, 599, 784	91.8%	5.3

Note that the prevalence of small HVAC systems is fairly high in most building types, reflecting their high overall market penetration. Notable exceptions are colleges and universities, health care, and large offices. Hotels and motels often have small through the wall or packaged terminal air conditioners (PTAC) serving guest rooms, which were excluded from this study due to their low overall market penetration.

Size of Buildings with Small HVAC Systems

Small HVAC systems appear in buildings of all sizes. Many large buildings are cooled by multiple small systems. The size of the unit is often dictated by the size of the HVAC zone within the building, not the overall size of the building. The NRNC database was queried to examine the average number of units as a function of building size. The results are shown in Figure 10:

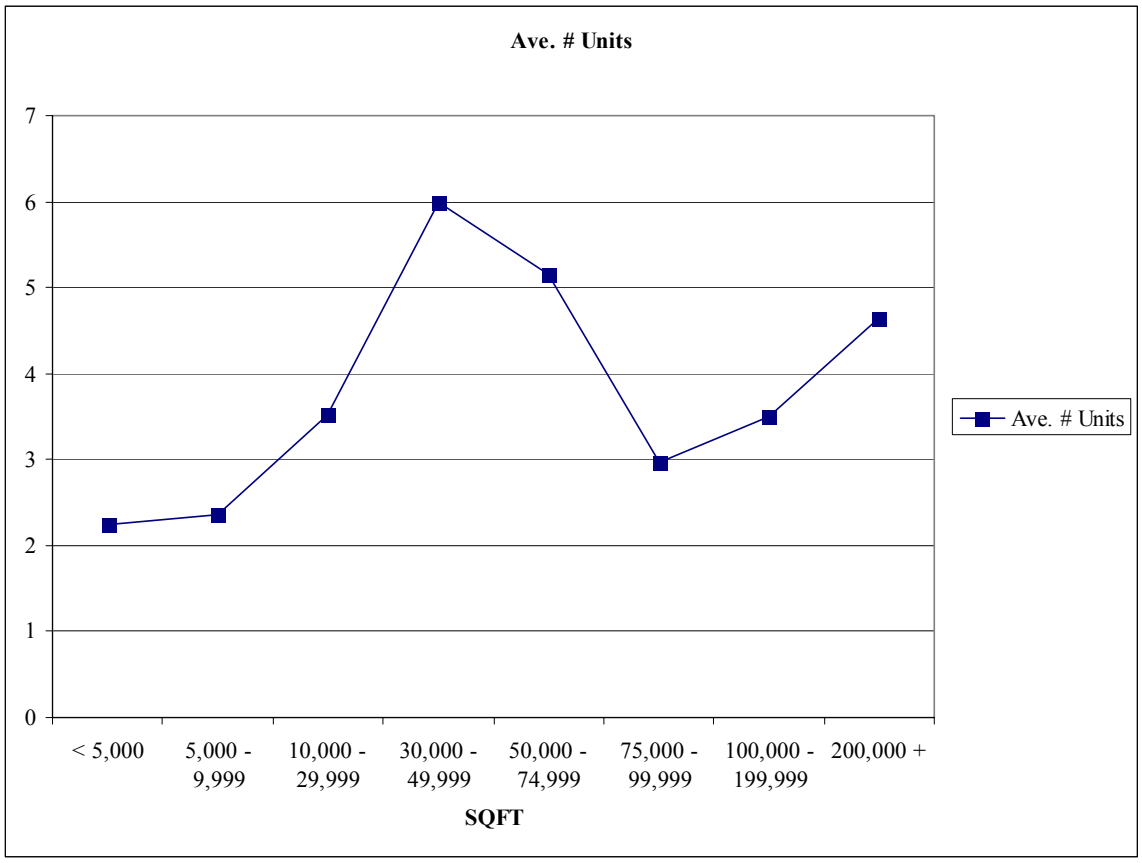


Figure 10. Average Number of Small Systems by Building Size

These data show a that buildings in the 30,000 to 50,000 ft^2 range have the most units per buidling on average. Larger buildings tend to have fewer small units per building, reflecting the use of units outside of the "small" category. Looking a the three most popular building types (office, retail and school), the average number of units per building as a funciton of system size is shown in Figure 11 below:

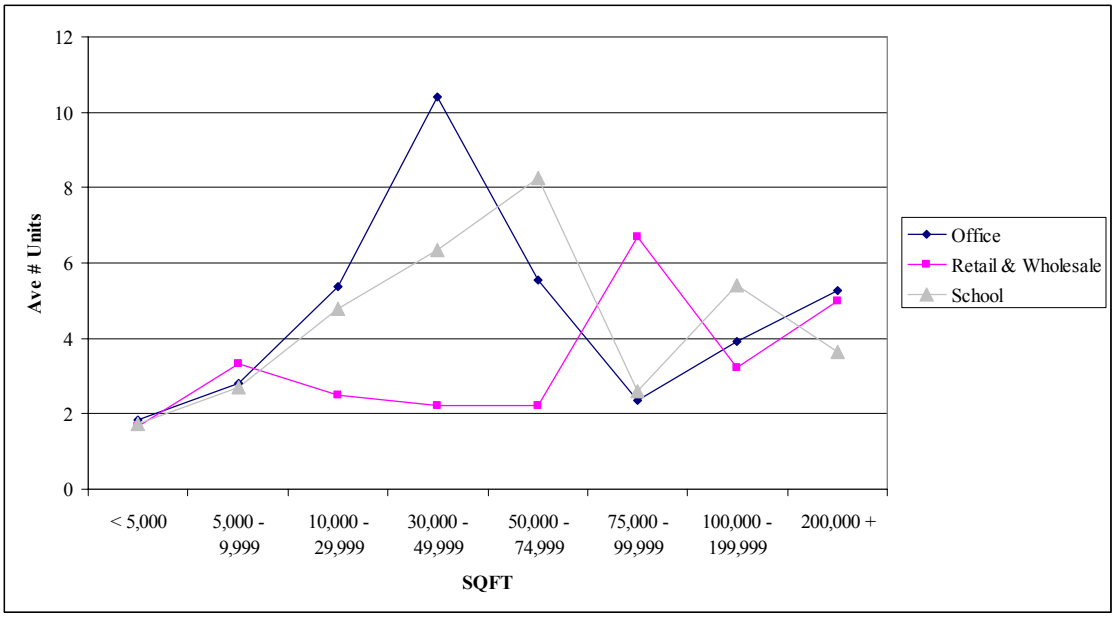


Figure 11. Average Number of Small Systems by Building Size in Offices, Retail, and Schools

Retail and wholesale stores up to 75,000 ft^2 tend to have two units per building on average, reflecting the relatively simple zoning strategies typical of these building types. Offices and schools show increasing number of units up to the 50,000 to 75,000 ft^2 size category, showing the use of multiple units to provide greater zoning capability in these buildings. The average number of units drop off above this size range, reflecting the use of fewer, larger units; some of which are outside the "small" size range.

Design Practices

Buildings are delivered to the owners using a variety of contracting mechanisms, including traditional Design-Bid-Build, Design/Build, Fast-track, and Negotiated Bid. A survey of architects was conducted by the California Board of Architectural Examiners (CBAE, 1999) to understand current and emerging trends in building delivery practices.

Table 2 below shows the response of architects to a survey questions regarding project delivery methods. The percentage of total revenue from architectural services categories are shown across the top, with the percentage of survey participants that selected each category are shown in each cell:

Table 2. Building Delivery Methods

	Percent total revenue from architectural services		
Delivery Process	0 – 25%	26 – 50%	51%+
Design-Bid-Build	39.9%	15.5%	44.6%
Design/Build	72.2%	13.4%	14.4%
Fast-track	82.0%	10.5%	7.3%
Negotiated Bid	56.3%	22.0%	21.7%
Project and Construction Management	67.2%	13.4%	19.4%

The survey concluded that while Design-Bid-Build is the most common builidng delivery processes, Design/Build will become more popular in the future.

A Nationwide survey of architects, engineers, and contractors was conducted by Air Conditioning and Refrigeration Technology Institute (ARTI) to get an understanding of the design practices used in the design of small (< 20,000 SF) buildings (Jacobs and Henderson, 2002). The survey concluded that manual methods (rules of thumb, simple nomographs, printed literature and forms) are the most popular design methods for all design decisions exept HVAC equipment sizing.

Table 3. Small Building Design Practices

Design Decision	Most Frequent Tool Used	% of Respondents
Building Form, Siting, and Orientation	Previous experience, rule of thumb	33
Lighting and Daylighting	Previous experience, rule of thumb	50
Envelope and Glazing	Previous experience, rule of thumb	38
HVAC Equipment Sizing	Manufacturers' sizing software	51
HVAC Equipment Selection	Manufacturers' literature	47
Refrigeration System Design	Manufacturers' literature	49
Green Design and Materials	Previous experience, rule of thumb	31
Energy Analysis and Code Compliance	Paper-based code compliance worksheets	27
Indoor Air Quality and Ventilation	ASHRAE Standard 62	37
Duct and pipe sizing	Nomograph tools (such as the "Ductilator")	57

The distribution of design methods for sizing HVAC systems is shown in Figure 12.

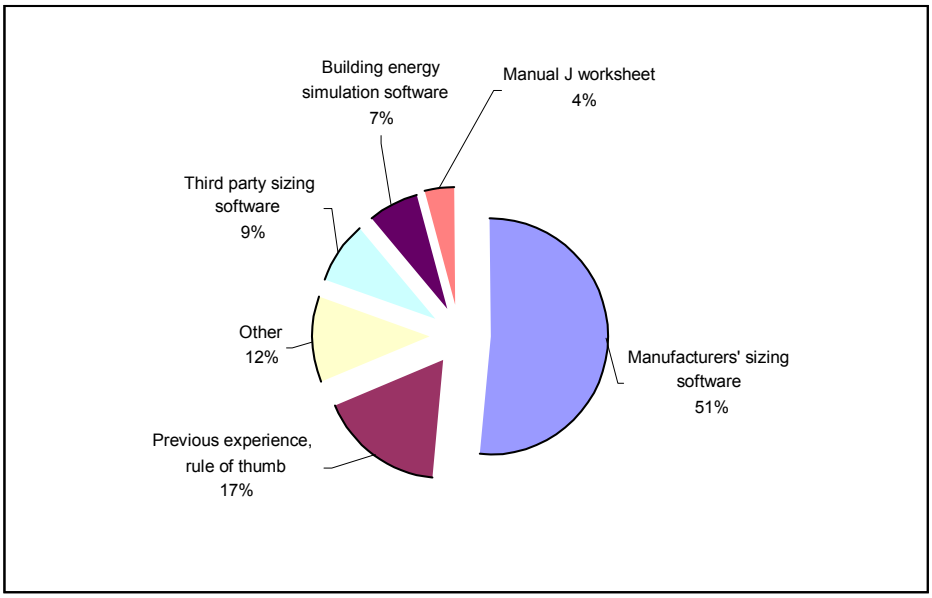


Figure 12. HVAC Sizing Design Methods

Note that HVAC equipment manufacturer-supplied software is the most commonly used tool for HVAC equipment sizing. Approximately two-thirds of the designers use some form of computerized sizing methods in the design of small commerical buildings. The study concluded that while most design decisions are made using simple design methods, the wide use of computerized design tools for HVAC system sizing opens the possibility for improved building systems integration using computerized sizing tools as the platform.

Energy Consumption

Simulation models were created for each building in the NRNC database using automated modeling software tied to the building characteristics data. The modeling software created a DOE-2.1E simulation model of each building, and the end-use energy consumption of each building was simulated. The energy consumption predicted for the population of buildings in the database was adjusted to reflect the CEC estimate of NRNC activity for the year 2001. The results are summarized in Table 4 as follows:

Table 4. Summary of NRNC floorspace and CEC New Construction Projections

Parameter	Value	Comments
Total floor space in NRNC database	233.2 million ft^2	Sum of weighted floor area in database
Estimated 2001 new construction activity	155.1 million ft^2	Excludes refrigerated warehouses
Adjustment factor	0.665	

The estimated end-use energy consumption for the statewide NRNC population, based on 2001 construction activity is shown in Table 5 below:

Table 5. Estimates of Statewide End-Use Consumption in New Construction

End-Use	Value	End-Use Share	Comments
Lighting	734 GWh	28.0%	Interior lighting only
Miscellaneous	840 GWh	32.1%	Includes plug, process, and exterior lighting loads
Cooling	356 GWh	13.6%	
Heating	16 GWh	0.6%	Primarily heat pumps and electric reheat
Fans	400 GWh	15.3%	
Refrigeration	274 GWh	10.4%	Primarily grocery store refrigeration systems with external condensers. Refrigerators reported as plug loads
Total	2619 GWh		

Estimates of HVAC energy consumption for small systems were developed by calculating the fraction of the floorspace in each building served by a packaged HVAC system, and multiplying this fraction by the estimated fraction of the total packaged system capacity that is represented by packaged DX units from 1 to 10 tons. These values are shown in Table 6 below:

Table 6. Estimates of Energy Consumption by Small HVAC Systems

End-Use	Small System Consumption	Fraction of NRNC Total End-Use Consumption
Cooling	111GWh	31%
Heating	7 GWh	47%
Fans	125 GWh	31%

SYSTEMS INTEGRATION PROBLEMS

Review of the literature on small HVAC systems applied to residential and commercial buildings provided insight into the types of problems expected in small systems applied to new commercial buildings. The problem areas identified include:

1. **Thermostats** . Small packaged HVAC units are generally applied as single zone systems, where each unit has its own thermostat and serves a discreet HVAC zone in the building. The HVAC unit responds to the room temperature measured in the vicinity of the thermostat. Poor placement can lead to comfort and energy waste when the local temperature is not representative of the zone air temperature. Multiple HVAC units controlled by independent thermostats in a single building can experience energy waste due to conflicting setpoints, which can cause simultaneous heating and cooling in adjacent zones.

2. **Fan controls** The primary function of the thermostat is to control the heating and cooling output of the unit, but most thermostats also control the operation of the supply fan.

Thermostats used in small HVAC systems may not have the capability or may not be programmed to implement the fan control provisions of Title 24. Many of these thermostats are low-cost "residential" style units that provide manual control of the fan operation. If the fan controls are set to "auto," the fans cycle with a call for heating or cooling, and fresh air is not continuously supplied to the zone. If the fan control is set to "on," the fans may run continuously day and night, wasting fan energy during the unoccupied hours. The energy impact of fan control strategies also has significant interactions with the distribution system efficiency, since leaky and poorly insulated ductwork in unconditioned spaces can introduce significant unwanted heat gain to the zone during fan operation.

3. **Economizers.** Economizers in small systems can save significant energy, yet are notoriously unreliable. Economizer failures generally do not result in comfort problems, and therefore may go undetected by the occupants. Problems with economizers include incorrect installation of system components, incorrect placement of sensors, and poor quality components (dampers, linkages, etc.), and failed components. Economizer control settings for single point temperature or enthalpy economizers vary by climate zone due to variations in local humidity levels, and may not be set properly by the installer. Since many small systems (especially those under 5 tons) use single stage compressors with no capacity control, simultaneous operation of the economizer and the compressor (integrated economizer) may not be possible. Systems integration issues with economizers include HVAC unit sizing and part-load control, and indoor air quality.

4. **System Sizing**. Field research into HVAC system operation has indicated that many HVAC systems are significantly oversized, resulting in inefficient operation, reduced reliability due to frequent cycling of compressors, and poor humidity control. Oversized systems also result in wasted capital investment in both the HVAC unit and distribution system. System oversizing also affects the ability of the system to provide simultaneous economizer and compressor operation, and exacerbates problems with distribution system fan power, since larger units are supplied with larger fans. Oversizing can increase the impacts of poor distribution system design, since larger duct systems present more surface area for heat transfer and greater air leakage potential.

5. **Distribution Systems**. The efficiency of the HVAC system is a function of both the unit efficiency and distribution system efficiency. Field research into distribution system efficiency in small commercial systems has shown that the impacts of duct leakage and poor duct insulation can be significant. The distribution system efficiency is a function of duct design and installation practices, as well as architectural design decisions affecting environmental conditions imposed the duct system. Architectural design issues affecting distribution system efficiency include insulation placement (roof or ceiling), roof surface and color selection, and location of attic vents.

6. **Condenser and Outdoor Air Entering Conditions**. The ambient temperature conditions encountered at the condenser coil inlet and the outdoor air intake can be much different than

the ambient air temperature. Local air heating can be caused by solar energy absorbed by the roof surface and heat rejection from adjacent HVAC units. Air flow restrictions around the units may inhibit the dissipation of these heat sources into the surrounding air, thereby raising the air temperature around the units. Impacts of elevated air temperatures include reduced HVAC unit efficiency and increased outdoor air cooling loads. Roof top air temperatures are affected by architectural and mechanical design decisions such as roofing material selection, parapet and unit screen design, and HVAC unit placement.

7. **Supply Fan Power**. HVAC unit efficiency is calculated from ARI standard test and rating procedures, which use a standard assumption for supply fan power to determine overall unit efficiency. The actual fan power may be greater than the standard assumption, reducing the installed efficiency of the unit. Fan power in small HVAC systems is not regulated by Title 24, and can be a significant energy cost, especially in systems utilizing continuous ventilation through the HVAC system. The specific fan power of the units as installed will be measured and compared to the ARI standard values. The supply fan power issue is related to fan controls and system sizing.

8. **Unit Air Flow**. Field tests of air flow in small HVAC systems in residences have shown that the units are operating outside the manufacturers' air flow rate recommendations. Additional studies on small commercial buildings have shown better compliance with manufacturers' guidelines, but more research is needed to fully understand the nature of the problem in commercial buildings. Low air flow can result in reduced system efficiency and coil icing. High air flow can also result in excessive fan energy and insufficient moisture removal.

9. **Refrigerant Charge.** Field tests of residential split systems have indicated widespread problems with refrigerant charge. Most units are installed with improper charge, reducing efficiency and capacity of the HVAC units. There is growing evidence that similar problems exist with single package systems installed in commercial buildings. The impact of improper charge is exacerbated by system oversizing, improper air flow, and the use of fixed-orifice or capillary tube expansion devices instead of thermostatic expansion valves.

10. **Maintenance Access**. Small HVAC systems are generally mounted on the roof of commercial buildings, and are "out of sight and out of mind." Maintenance access to these units can be limited, depending on unit layout, access to the roof by service personnel, architectural features and interior design. Efficient operation of small HVAC systems depends on regular maintenance, which can be difficult if access to the roof or unit service panels is blocked.

Prior Research Summary

An extensive literature review was undertaken to identify prior research relevant to this project. A list of the references reviewed is included at the end of the document. A summary of a few key studies in each topic area is shown in Table 7. Potential energy impacts from avoiding these problems in new commercial buildings is also listed.

Table 7. Summary of Selected Prior Research Studies

Topic area	Organization	Summary	Potential Savings
Fan controls	LBNL	Nine of ten small commercial buildings studied had intermittent fan operation	Energy increase
	AEC for PG&E	On-site surveys indicated up to 50% of buildings surveyed had intermittent fan operation. Effective ventilation rates reduced to about 5 cfm/person	66% red. in OA
Economizers	Don Felts for PG&E	Short term monitoring study of 250 rooftop units for PG&E. Only 16% of the units had a functioning economizer.	5% - 50+%
System sizing	Don Felts for PG&E	Short term monitoring study of 250 rooftop units for PG&E. Oversizing of systems evident. Over 60% of the units had at least 3 on/off cycles per hour under peak load conditions	10%
	Vermont Energy Investment Corp	Summary of national studies on residential AC and heat pump installation problems, including sizing, refrigerant charge, airflow and distribution systems	
Distribution Systems	LBNL	Half of the small commercial buildings studied have duct systems outside the conditioned envelope. Leakage rates are much greater than residential systems	20%
	FSEC	33 out of the 70 commercial buildings tested used building cavities as air distribution systems; many of these were outside either the building thermal or air (infiltration) barrier.	
	John Proctor	Residential studies in California, New Jersey and Florida estimate 15% to 20% energy savings from duct leakage sealing	
Supply Fan Power	John Proctor, FSEC	Residential monitoring studies in Arizona, California, New Jersey, Nevada and Florida show installed fan energy exceeds ARI assumptions	5% - 6%

Table 7. Summary of Selected Prior Research Studies (continued)

Unit Air Flow	LBNL	Measurements of air flow on small commercial buildings show air flow rates generally do not meet manufacturers' recommendations, although the problem is not as severe as in residential buildings	10%
	John Proctor, FSEC	Residential monitoring studies in Arizona, California, New Jersey, Nevada and Florida show installed fan energy exceeds ARI assumptions	
Refrigerant Charge	John Proctor	Residential charge testing studies in California, and New Jersey show 60% of units improperly charged	10% - 20%
	John Proctor	CheckME database on refrigerant charge in small commercial buildings show similar levels of improper charge as in residential buildings.	

The energy savings potential from avoiding each problems listed above are highly interactive, so the net effect from avoiding a combination of problems will certainly be less than the sum of the individual effects. However, many of the problems identified above have potential impacts that exceed the 10% energy savings goal established for this project. The challenge will be to identify product/system improvement opportunities that will achieve sufficient market penetration to avoid these problems in enough new buildings to achieve a 10% overall energy savings.

Current and Planned Activities—Research, Market Transformation, and Resource Acquisition

Several current and planned research projects that are related to this project have been identified. The project team will attempt to coordinate with these efforts to avoid duplication and leverage the research results. The key current and future projects are listed in Table 8 below:

Table 8. Summary of Related Current and Planned Research

Project / Researcher	Sponsor	Description
Duct sealing and refrigerant charge testing in small commercial buildings in Southern California. / John Proctor and Mark Modera	SCE	Resource acquisition project will correct charge and seal ductwork in about 250 buildings this summer. No monitoring planned but pre/post charge and duct leakage data available.
LBNL Pier Project Element 4 - Low Energy Cooling. / Mark Modera	CEC	Development of analytical procedures to model the impacts of distribution efficiency improvements. May involve adjustments to overall system efficiency and/or enhancements to EnergyPlus
2005 Update to Title 24 / Charles Eley et al.	CEC	Updates to 2005 Title 24 non-residential standards will be studied. Topics include sizing, fan energy, refrigerant charge, T-bar ceilings and computer modeling
Codes and Standards Enhancement Initiative / Heshong – Mahone Group et al.	PG&E	Updates to 2005 Title 24 non-residential standards will be studied. Topics include field verification procedures for tight ducts and economizers

APPENDIX A: BIBLIOGRAPHY

Brambley M., Pratt R., Chassin D., Katipamula S., and Hatley D. "Diagnostics for Outdoor Air Ventilation and Economizers." *ASHRAE Journal*. October 1998

Braun, James and Breuker, Mark. "Common Faults and Their Impacts for Rooftop Air Conditioners." *HVAC&R Research*. Vol. 4. No. 3. July 1998

Braun, James and Breuker, Mark. "Evaluating the Performance of a Fault Detection and Diagnostic System for Vapor Compression Equipment." *HVAC&R Research*. Vol. 4. No. 4. October 1998

Breuker M., Rossi T., and Braun J. "Smart Maintenance for Rooftop Units." *ASHRAE Journal*. November 2000.

Building and Appliance Efficiency Office of the Energy Efficiency and Local Assistance Division of the California Energy Commission. "Package Rooftop Economizer Study." Building Energy Efficiency Standards.

California Board of Architectural Examiners. "Trends in Practice Report," CBAE, Sacramento, CA 1999.

Consortium for Energy Efficiency. "Specification of Energy-Efficient Installation and Maintenance Practices for Residential HVAC Systems."

Consortium for Energy Efficiency. "Guidelines for Energy Efficient Commercial Unitary HVAC Systems," Consortium for Energy Efficiency, Boston MA 2001

Consortium for Energy Efficiency. "White Paper for the Guidelines for Energy Efficient Commercial Unitary HVAC Systems," Consortium for Energy Efficiency, Boston MA 2001

Delp W., Matson N., Tschudy E., Modera M., and Diamond R. "Field Investigation of Duct System Performance in California Light Commercial Buildings." Lawrence Berkeley National Laboratory report No. 40102.

Don Felts Energy Consultant. "Roof Top Unit Economizer Feasibility Study." Prepared for Pacific Gas and Electric Company. August 25, 2000.

Eley Associates. "Assembly Bill 970 Building Energy Efficiency Standards: Split Systems Space Cooling Refrigerant Charge and Airflow Measurement." Prepared for the California Energy Commission. March 20, 2001.

Felts, Don. "Roof Top Unit Technical Potential Assessment." Pacific Gas and Electric Company. 2001

Felts, Don and Bailey, Patrick. "The State of Affairs – packaged Cooling Equipment in California." ACEEE 2000.

Gartland L., Konopaski S., and Akbari H. "Modeling the Effects of Reflective Roofing." Ernest Orlando Lawrence Berkeley National Laboratory. August 1996.

Haves P., Salsbury T., and Wright J., "Condition Monitoring in HVAC Subsystems Using First Principles Models." *ASHRAE Transactions: Symposia*. 1996.

Henderson, H.I. "Simulating Combines Thermostat, Air conditioner, and Building Performance in a House." *ASHRAE Transactions*. Vol 98. Part 1 1992

Herzog, Peter and LaVine, Lance. "Identification and Quantification of the Impact of Improper Operation of Midsize Minnesota Office Buildings on Energy Use: A Seven Building Case Study." ACEEE 1992

Hewett M., Bohac D., Landry R., Dunsworth T., Englander S., and Peterson G. "Measured Energy and Demand Impacts of Efficiency Tune-ups for Small Commercial Cooling Systems." ACEEE 1992.

Houghton, David. "Operating and Maintaining Rooftop Air-Conditioning Units." *E source.* January 1997.

James, P., Cummings, J.E., Sonne, J., Vieira, R., and Klongerbo, J. "The Effect of Residential Equipment Capacity on Energy Use, Demand, and Run-Time." 2001 http://www.fsec.ucf.edu/~bdac/pubs/PF328/capacity.htm

Jacobs, P. and Henderson, H. "State-of-the-Art Review: Whole Building, Building Envelope, and HVAC Component and System Simulation and Design Tools," ARTI-21CR-605-30010-30020-01. Air Conditioning and Refrigeration Technology Institute, Arlington, VA. 2002.

Jerkins, Virginia. "Heat Pump Study: Tricks of the Trade That Can Pump Up Efficiency." *Home Energy*. March/April 1996.

Jump, D., Walker, I., and Modera, M. "Field Measurements of Efficiency and Duct Retrofit Effectiveness in Residential Forced air Distribution Systems." ACEEE Summer Study. August 1996

Katipamula S., Pratt R., Chassin D., Taylor T., Gowri K., and Brambley M. "Automated Fault Detection and Diagnostics for Outdoor-Air Ventilation Systems and Economizers: Methodology and Results from Field Testing." *ASHREA Transactions* 1999, Vol. 105, Pt. 1

Kopko, William and Hibberd, Douglas. "Design of a High-Efficiency Rooftop Air Conditioner." ACEEE 1994

Krakow K., Zhao F., and Muhsin A. "Economizer Control." *ASHRAE Transactions* 2000. Vol. 106, Pt 2.

Lunneberg, Tom. "When Good Economizers Go Bad: Keeping This Air-Side Energy Saver on the Upside." *E source*. ER-99-14. September 1999.

Modera, Mark. "Two Favorite Test Methods, By the Book." *Home Energy Online*. September/October 1993.

Modera, M., Dickerhoff, D., Nilssen, O., Duquette, H., and Geyselaers, J. "Residential Field Testing of an Aerosol-Based Technology for Sealing Ductwork." ACEEE. 1996

Moujaes, Samir and Brickman, Richard. "Effect of a Radiant Barrier on the Cooling Load of a Residential Application in a Hot and Arid Region: Attic Duct Effect." *HVAC&R Research*. Vol. 4. No. 3. July 1998.

Neal, Leon. "Air Conditioner Efficiency in the Real World." *Home Energy*. May/June 1992

Peterson, George and Proctor, John. "Effects of Occupant Control, System Parameters, and Program Measures on Residential Air Conditioner Peak Loads." ACEEE. 1998.

Proctor Engineering group, LTD. "Support Documentation for John Proctor's Comments on the Central AC and heat Pump NOPR." December, 2000.

Proctor, John. "An Ounce of Prevention: Residential Cooling Repairs." *Home Energy*. May/June 1991. http://hem.dis.anl.gov/eehem/93/930912.htm

Proctor, John and Parker, Danny. "Hidden Power Drains: Trends in Residential Heating and Cooling Fan Watt Power Demand." 2001. http://www.fsec.ufc.edu/%7Edbac/pubs/pf361/pf361/html

Rossi, Todd and Braun, James. "A Statistical, Rule-Based Fault Detection and Diagnostic Method for Vapor Compression Air Conditioners." *HVAC&R Research*. Vol. 3. No. 1. January 1997

Sherman, M.H. and Wilson, D.J. "Relating Actual and Effective Ventilation in Determining Indoor Air Quality" *Building and Environment*, Vol. 21. No. ¾. pp. 135-144. 1986.

Shugars J., Coleman P., Payne C., and McGrory L. "Bridging the Efficiency Gap: Commercial Packaged Rooftop Air Conditioners." ACEEE 2000.

Silver, S., Fine, P., and Rose, F. "Performance Monitoring of DX Rooftop cooling Equipment." *Energy Engineering*. Vol. 87, No. 5. 1990

Texas Utilities. "Measurements and Verification Guidelines for Duct Sealing Measures." *TXU Measurement and Verification Guidelines*.

Wilcox, Bruce and Hunt, Marshall. "Comparison of CHEERS Energy Use Predictions with Actual Utility Bills." ACEEE 1998 Summer Study. June 29, 1998.

Wray C., Matson N., and Sherman M. "Whole-House Ventilation Strategies to Meet Proposed Standard 62.2: Energy Cost Considerations." *ASHRAE Transactions* 2000. Vol. 106. Pt. 2.

Xu, T., Modera, M., and Carrie, R. "Performance Diagnostics of Thermal distribution Systems in Light Commercial Buildings." ACEEE. 2000.

APPENDIX B: STANDARD INDUSTRIAL CLASSIFICATION

SIC Code	Description
101	IRON ORES
102	COPPER ORES
103	LEAD AND ZINC ORES
104	GOLD AND SILVER ORES
106	FERROALLOY ORES, EXCEPT VANADIUM
108	METAL MINING SERVICES
109	MISCELLANEOUS METAL ORES
122	BITUMINOUS COAL AND LIGNITE MINING
123	ANTHRACITE MINING
124	COAL MINING SERVICES
131	CRUDE PETROLEUM AND NATURAL GAS
132	NATURAL GAS LIQUIDS
138	OIL AND GAS FIELD SERVICES
141	DIMENSION STONE
142	CRUSHED AND BROKEN STONE, INCLUDING RIPRAP
144	SAND AND GRAVEL
145	CLAY, CERAMIC, AND REFRACTORY MINERALS
147	CHEMICAL AND FERTILIZER MINERAL MINING
148	NONMETALLIC MINERALS SERVICES, EXCEPT FUELS
149	MISCELLANEOUS NONMETALLIC MINERALS, EXCEPT FUELS
152	GENERAL BUILDING CONTRACTORS-RESIDENTIAL BUILDINGS
153	OPERATIVE BUILDERS
154	GENERAL BUILDING CONTRACTORS-NONRESIDENTIAL BUILDINGS
161	HIGHWAY AND STREET CONSTRUCTION, EXCEPT ELEVATED HIGHWAYS
162	HEAVY CONSTRUCTION, EXCEPT HIGHWAY AND STREET CONSTRUCTION
171	PLUMBING, HEATING AND AIR-CONDITIONING
172	PAINTING AND PAPER HANGING
173	ELECTRICAL WORK
174	MASONRY, STONEWORK, TILE SETTING, AND PLASTERING
175	CARPENTRY AND FLOOR WORK
176	ROOFING, SIDING, AND SHEET METAL WORK

SIC Code	Description
177	CONCRETE WORK
178	WATER WELL DRILLING
179	MISCELLANEOUS SPECIAL TRADE CONTRACTORS
201	MEAT PRODUCTS
202	DAIRY PRODUCTS
203	CANNED, FROZEN, AND PRESERVED FRUITS, VEGETABLES, AND FOOD SPECIALTIES
204	GRAIN MILL PRODUCTS
205	BAKERY PRODUCTS
206	SUGAR AND CONFECTIONERY PRODUCTS
207	FATS AND OILS
208	BEVERAGES
209	MISCELLANEOUS FOOD PREPARATIONS AND KINDRED PRODUCTS
211	CIGARETTES
212	CIGARS
213	CHEWING AND SMOKING TOBACCO AND SNUFF
214	TOBACCO STEMMING AND REDRYING
221	BROADWOVEN FABRIC MILLS, COTTON
222	BROADWOVEN FABRIC MILLS, MANMADE FIBER AND SILK
223	BROADWOVEN FABRIC MILLS, WOOL (INCLUDING DYEING AND FINISHING)
224	NARROW FABRIC AND OTHER SMALLWARES MILLS: COTTON, WOOL, SILK, AND MANMADE FIBER
225	KNITTING MILLS
226	DYEING AND FINISHING TEXTILES, EXCEPT WOOL FABRICS AND KNIT GOODS
227	CARPETS AND RUGS
228	YARN AND THREAD MILLS
229	MISCELLANEOUS TEXTILE GOODS
231	MEN'S AND BOYS' SUITS, COATS, AND OVERCOATS
232	MEN'S AND BOYS' FURNISHINGS, WORK CLOTHING, AND ALLIED GARMENTS
233	WOMEN'S, MISSES', AND JUNIORS' OUTERWEAR
234	WOMEN'S, MISSES', CHILDREN'S, AND INFANTS' UNDERGARMENTS
235	HATS, CAPS, AND MILLINERY
236	GIRLS', CHILDREN'S, AND INFANTS' OUTERWEAR

SIC Code	Description
237	FUR GOODS
238	MISCELLANEOUS APPAREL AND ACCESSORIES
239	MISCELLANEOUS FABRICATED TEXTILE PRODUCTS
241	LOGGING
242	SAWMILLS AND PLANING MILLS
243	MILLWORK, VENEER, PLYWOOD, AND STRUCTURAL WOOD MEMBERS
244	WOOD CONTAINERS
245	WOOD BUILDINGS AND MOBILE HOMES
249	MISCELLANEOUS WOOD PRODUCTS
251	HOUSEHOLD FURNITURE
252	OFFICE FURNITURE
253	PUBLIC BUILDING AND RELATED FURNITURE
254	PARTITIONS, SHELVING, LOCKERS, AND OFFICE AND STORE FIXTURES
259	MISCELLANEOUS FURNITURE AND FIXTURES
261	PULP MILLS
262	PAPER MILLS
263	PAPERBOARD MILLS
265	PAPERBOARD CONTAINERS AND BOXES
267	CONVERTED PAPER AND PAPERBOARD PRODUCTS, EXCEPT CONTAINERS AND BOXES
271	NEWSPAPERS: PUBLISHING, OR PUBLISHING AND PRINTING
272	PERIODICALS: PUBLISHING, OR PUBLISHING AND PRINTING
273	BOOKS
274	MISCELLANEOUS PUBLISHING
275	COMMERCIAL PRINTING
276	MANIFOLD BUSINESS FORMS
277	GREETING CARDS
278	BLANKBOOKS, LOOSELEAF BINDERS, AND BOOKBINDING AND RELATED WORK
279	SERVICE INDUSTRIES FOR THE PRINTING TRADE
281	INDUSTRIAL INORGANIC CHEMICALS
282	PLASTICS MATERIALS AND SYNTHETIC RESINS, SYNTHETIC RUBBER, CELLULOSIC AND OTHER
283	DRUGS
284	SOAP, DETERGENTS, AND CLEANING PREPARATIONS; PERFUMES, COSMETICS, AND OTHER TOIL

SIC Code	Description
285	PAINTS, VARNISHES, LACQUERS, ENAMELS, AND ALLIED PRODUCTS
286	INDUSTRIAL ORGANIC CHEMICALS
287	AGRICULTURAL CHEMICALS
289	MISCELLANEOUS CHEMICAL PRODUCTS
291	PETROLEUM REFINING
295	ASPHALT PAVING AND ROOFING MATERIALS
299	MISCELLANEOUS PRODUCTS OF PETROLEUM AND COAL
301	TIRES AND INNER TUBES
302	RUBBER AND PLASTICS FOOTWEAR
305	GASKETS, PACKING, AND SEALING DEVICES AND RUBBER AND PLASTICS HOSE AND BELTING
306	FABRICATED RUBBER PRODUCTS, NOT ELSEWHERE CLASSIFIED
308	MISCELLANEOUS PLASTICS PRODUCTS
311	LEATHER TANNING AND FINISHING
313	BOOT AND SHOE CUT STOCK AND FINDINGS
314	FOOTWEAR, EXCEPT RUBBER
315	LEATHER GLOVES AND MITTENS
316	LUGGAGE
317	HANDBAGS AND OTHER PERSONAL LEATHER GOODS
319	LEATHER GOODS, NOT ELSEWHERE CLASSIFIED
321	FLAT GLASS
322	GLASS AND GLASSWARE, PRESSED OR BLOWN
323	GLASS PRODUCTS, MADE OF PURCHASED GLASS
324	CEMENT, HYDRAULIC
325	STRUCTURAL CLAY PRODUCTS
326	POTTERY AND RELATED PRODUCTS
327	CONCRETE, GYPSUM, AND PLASTER PRODUCTS
328	CUT STONE AND STONE PRODUCTS
329	ABRASIVE, ASBESTOS, AND MISCELLANEOUS NONMETALLIC MINERAL PRODUCTS
331	STEEL WORKS, BLAST FURNACES, AND ROLLING AND FINISHING MILLS
332	IRON AND STEEL FOUNDRIES
333	PRIMARY SMELTING AND REFINING OF NONFERROUS METALS
334	SECONDARY SMELTING AND REFINING OF NONFERROUS METALS
335	ROLLING, DRAWING, AND EXTRUDING OF NONFERROUS METALS

SIC Code	Description
336	NONFERROUS FOUNDRIES (CASTINGS)
339	MISCELLANEOUS PRIMARY METAL PRODUCTS
341	METAL CANS AND SHIPPING CONTAINERS
342	CUTLERY, HANDTOOLS, AND GENERAL HARDWARE
343	HEATING EQUIPMENT, EXCEPT ELECTRIC AND WARM AIR; AND PLUMBING FIXTURES
344	FABRICATED STRUCTURAL METAL PRODUCTS
345	SCREW MACHINE PRODUCTS, AND BOLTS, NUTS, SCREWS, RIVETS, AND WASHERS
346	METAL FORGINGS AND STAMPINGS
347	COATING, ENGRAVING, AND ALLIED SERVICES
348	ORDNANCE AND ACCESSORIES, EXCEPT VEHICLES AND GUIDED MISSILES
349	MISCELLANEOUS FABRICATED METAL PRODUCTS
351	ENGINES AND TURBINES
352	FARM AND GARDEN MACHINERY AND EQUIPMENT
353	CONSTRUCTION, MINING, AND MATERIALS HANDLING MACHINERY AND EQUIPMENT
354	METALWORKING MACHINERY AND EQUIPMENT
355	SPECIAL INDUSTRY MACHINERY, EXCEPT METALWORKING MACHINERY
356	GENERAL INDUSTRIAL MACHINERY AND EQUIPMENT
357	COMPUTER AND OFFICE EQUIPMENT
358	REFRIGERATION AND SERVICE INDUSTRY MACHINERY
359	MISCELLANEOUS INDUSTRIAL AND COMMERCIAL MACHINERY AND EQUIPMENT
361	ELECTRIC TRANSMISSION AND DISTRIBUTION EQUIPMENT
362	ELECTRICAL INDUSTRIAL APPARATUS
363	HOUSEHOLD APPLIANCES
364	ELECTRIC LIGHTING AND WIRING EQUIPMENT
365	HOUSEHOLD AUDIO AND VIDEO EQUIPMENT, AND AUDIO RECORDINGS
366	COMMUNICATIONS EQUIPMENT
367	ELECTRONIC COMPONENTS AND ACCESSORIES
369	MISCELLANEOUS ELECTRICAL MACHINERY, EQUIPMENT, AND SUPPLIES
371	MOTOR VEHICLES AND MOTOR VEHICLE EQUIPMENT
372	AIRCRAFT AND PARTS
373	SHIP AND BOAT BUILDING AND REPAIRING
374	RAILROAD EQUIPMENT

SIC Code	Description
375	MOTORCYCLES, BICYCLES, AND PARTS
376	GUIDED MISSILES AND SPACE VEHICLES AND PARTS
379	MISCELLANEOUS TRANSPORTATION EQUIPMENT
381	SEARCH, DETECTION, NAVIGATION, GUIDANCE, AERONAUTICAL, AND NAUTICAL SYSTEMS, INS
382	LABORATORY APPARATUS AND ANALYTICAL, OPTICAL, MEASURING, AND CONTROLLING INSTRUM
384	SURGICAL, MEDICAL, AND DENTAL INSTRUMENTS AND SUPPLIES
385	OPHTHALMIC GOODS
386	PHOTOGRAPHIC EQUIPMENT AND SUPPLIES
387	WATCHES, CLOCKS, CLOCKWORK OPERATED DEVICES, AND PARTS
391	JEWELRY, SILVERWARE, AND PLATED WARE
393	MUSICAL INSTRUMENTS
394	DOLLS, TOYS, GAMES AND SPORTING AND ATHLETIC GOODS
395	PENS, PENCILS, AND OTHER ARTISTS' MATERIALS
396	COSTUME JEWELRY, COSTUME NOVELTIES, BUTTONS, AND MISCELLANEOUS NOTIONS, EXCEPT P
399	MISCELLANEOUS MANUFACTURING INDUSTRIES
401	RAILROADS
411	LOCAL AND SUBURBAN PASSENGER TRANSPORTATION
412	TAXICABS
413	INTERCITY AND RURAL BUS TRANSPORTATION
414	BUS CHARTER SERVICE
415	SCHOOL BUSES
417	TERMINAL AND SERVICE FACILITIES FOR MOTOR VEHICLE PASSENGER TRANSPORTATION
421	TRUCKING AND COURIER SERVICES, EXCEPT AIR
422	PUBLIC WAREHOUSING AND STORAGE
423	TERMINAL AND JOINT TERMINAL MAINTENANCE FACILITIES FOR MOTOR FREIGHT TRANSPORTAT
431	UNITED STATES POSTAL SERVICE
441	DEEP SEA FOREIGN TRANSPORTATION OF FREIGHT
442	DEEP SEA DOMESTIC TRANSPORTATION OF FREIGHT
443	FREIGHT TRANSPORTATION ON THE GREAT LAKES ST. LAWRENCE SEAWAY
444	WATER TRANSPORTATION OF FREIGHT, NOT ELSEWHERE CLASSIFIED

SIC Code	Description
448	WATER TRANSPORTATION OF PASSENGERS
449	SERVICES INCIDENTAL TO WATER TRANSPORTATION
451	AIR TRANSPORTATION, SCHEDULED, AND AIR COURIER SERVICES
452	AIR TRANSPORTATION, NONSCHEDULED
458	AIRPORTS, FLYING FIELDS, AND AIRPORT TERMINAL SERVICES
461	PIPELINES, EXCEPT NATURAL GAS
472	ARRANGEMENT OF PASSENGER TRANSPORTATION
473	ARRANGEMENT OF TRANSPORTATION OF FREIGHT AND CARGO
474	RENTAL OF RAILROAD CARS
478	MISCELLANEOUS SERVICES INCIDENTAL TO TRANSPORTATION
481	TELEPHONE COMMUNICATIONS
482	TELEGRAPH AND OTHER MESSAGE COMMUNICATIONS
483	RADIO AND TELEVISION BROADCASTING STATIONS
484	CABLE AND OTHER PAY TELEVISION SERVICES
489	COMMUNICATIONS SERVICES, NOT ELSEWHERE CLASSIFIED
491	ELECTRIC SERVICES
492	GAS PRODUCTION AND DISTRIBUTION
493	COMBINATION ELECTRIC AND GAS, AND OTHER UTILITY SERVICES
494	WATER SUPPLY
495	SANITARY SERVICES
496	STEAM AND AIR-CONDITIONING SUPPLY
497	IRRIGATION SYSTEMS
501	MOTOR VEHICLES AND MOTOR VEHICLE PARTS AND SUPPLIES
502	FURNITURE AND HOMEFURNISHINGS
503	LUMBER AND OTHER CONSTRUCTION MATERIALS
504	PROFESSIONAL AND COMMERCIAL EQUIPMENT AND SUPPLIES
505	METALS AND MINERALS, EXCEPT PETROLEUM
506	ELECTRICAL GOODS
507	HARDWARE, AND PLUMBING AND HEATING EQUIPMENT AND SUPPLIES
508	MACHINERY, EQUIPMENT, AND SUPPLIES
509	MISCELLANEOUS DURABLE GOODS
511	PAPER AND PAPER PRODUCTS
512	DRUGS, DRUG PROPRIETARIES, AND DRUGGISTS' SUNDRIES
513	APPAREL, PIECE GOODS, AND NOTIONS

SIC Code	Description
514	GROCERIES AND RELATED PRODUCTS
515	FARM-PRODUCT RAW MATERIALS
516	CHEMICALS AND ALLIED PRODUCTS
517	PETROLEUM AND PETROLEUM PRODUCTS
518	BEER, WINE, AND DISTILLED ALCOHOLIC BEVERAGES
519	MISCELLANEOUS NONDURABLE GOODS
521	LUMBER AND OTHER BUILDING MATERIALS DEALERS
523	PAINT, GLASS, AND WALLPAPER STORES
525	HARDWARE STORES
526	RETAIL NURSERIES, LAWN AND GARDEN SUPPLY STORES
527	MOBILE HOME DEALERS
531	DEPARTMENT STORES
533	VARIETY STORES
539	MISCELLANEOUS GENERAL MERCHANDISE STORES
541	GROCERY STORES
542	MEAT AND FISH (SEAFOOD) MARKETS, INCLUDING FREEZER PROVISIONERS
543	FRUIT AND VEGETABLE MARKETS
544	CANDY, NUT, AND CONFECTIONERY STORES
545	DAIRY PRODUCTS STORES
546	RETAIL BAKERIES
549	MISCELLANEOUS FOOD STORES
551	MOTOR VEHICLE DEALERS (NEW AND USED)
552	MOTOR VEHICLE DEALERS (USED ONLY)
553	AUTO AND HOME SUPPLY STORES
554	GASOLINE SERVICE STATIONS
555	BOAT DEALERS
556	RECREATIONAL VEHICLE DEALERS
557	MOTORCYCLE DEALERS
559	AUTOMOTIVE DEALERS, NOT ELSEWHERE CLASSIFIED
561	MEN'S AND BOYS' CLOTHING AND ACCESSORY STORES
562	WOMEN'S CLOTHING STORES
563	WOMEN'S ACCESSORY AND SPECIALTY STORES
564	CHILDREN'S AND INFANTS' WEAR STORES
565	FAMILY CLOTHING STORES

SIC Code	Description
566	SHOE STORES
569	MISCELLANEOUS APPAREL AND ACCESSORY STORES
571	HOME FURNITURE AND FURNISHINGS STORES
572	HOUSEHOLD APPLIANCE STORES
573	RADIO, TELEVISION, CONSUMER ELECTRONICS, AND MUSIC STORES
581	EATING AND DRINKING PLACES
591	DRUG STORES AND PROPRIETARY STORES
592	LIQUOR STORES
593	USED MERCHANDISE STORES
594	MISCELLANEOUS SHOPPING GOODS STORES
596	NONSTORE RETAILERS
598	FUEL DEALERS
599	RETAIL STORES, NOT ELSEWHERE CLASSIFIED
601	CENTRAL RESERVE DEPOSITORY INSTITUTIONS
602	COMMERCIAL BANKS
603	SAVINGS INSTITUTIONS
606	CREDIT UNIONS
608	FOREIGN BANKING AND BRANCHES AND AGENCIES OF FOREIGN BANKS
609	FUNCTIONS RELATED TO DEPOSITORY BANKING
611	FEDERAL AND FEDERALLY-SPONSORED CREDIT AGENCIES
614	PERSONAL CREDIT INSTITUTIONS
615	BUSINESS CREDIT INSTITUTIONS
616	MORTGAGE BANKERS AND BROKERS
621	SECURITY BROKERS, DEALERS, AND FLOTATION COMPANIES
622	COMMODITY CONTRACTS BROKERS AND DEALERS
623	SECURITY AND COMMODITY EXCHANGES
628	SERVICES ALLIED WITH THE EXCHANGE OF SECURITIES OR COMMODITIES
631	LIFE INSURANCE
632	ACCIDENT AND HEALTH INSURANCE AND MEDICAL SERVICE PLANS
633	FIRE, MARINE, AND CASUALTY INSURANCE
635	SURETY INSURANCE
636	TITLE INSURANCE
637	PENSION, HEALTH, AND WELFARE FUNDS
639	INSURANCE CARRIERS, NOT ELSEWHERE CLASSIFIED

SIC Code	Description
641	INSURANCE AGENTS, BROKERS, AND SERVICE
651	REAL ESTATE OPERATORS (EXCEPT DEVELOPERS) AND LESSORS
653	REAL ESTATE AGENTS AND MANAGERS
654	TITLE ABSTRACT OFFICES
655	LAND SUBDIVIDERS AND DEVELOPERS
671	HOLDING OFFICES
672	INVESTMENT OFFICES
673	TRUSTS
679	MISCELLANEOUS INVESTING
701	HOTELS AND MOTELS
702	ROOMING AND BOARDING HOUSES
703	CAMPS AND RECREATIONAL VEHICLE PARKS
704	ORGANIZATION HOTELS AND LODGING HOUSES, ON MEMBERSHIP BASIS
721	LAUNDRY, CLEANING, AND GARMENT SERVICES
722	PHOTOGRAPHIC STUDIOS, PORTRAIT
723	BEAUTY SHOPS
724	BARBER SHOPS
725	SHOE REPAIR SHOPS AND SHOESHINE PARLORS
726	FUNERAL SERVICE AND CREMATORIES
729	MISCELLANEOUS PERSONAL SERVICES
731	ADVERTISING
732	CONSUMER CREDIT REPORTING AGENCIES, MERCANTILE REPORTING AGENCIES, AND ADJUSTMEN
733	MAILING, REPRODUCTION, COMMERCIAL ART AND PHOTOGRAPHY, AND STENOGRAPHIC SERVICES
734	SERVICES TO DWELLINGS AND OTHER BUILDINGS
735	MISCELLANEOUS EQUIPMENT RENTAL AND LEASING
736	PERSONNEL SUPPLY SERVICES
737	COMPUTER PROGRAMMING, DATA PROCESSING, AND OTHER COMPUTER RELATED SERVICES
738	MISCELLANEOUS BUSINESS SERVICES
751	AUTOMOTIVE RENTAL AND LEASING, WITHOUT DRIVERS
752	AUTOMOBILE PARKING
753	AUTOMOTIVE REPAIR SHOPS
754	AUTOMOTIVE SERVICES, EXCEPT REPAIR

SIC Code	Description
762	ELECTRICAL REPAIR SHOPS
763	WATCH, CLOCK, AND JEWELRY REPAIR
764	REUPHOLSTERY AND FURNITURE REPAIR
769	MISCELLANEOUS REPAIR SHOPS AND RELATED SERVICES
781	MOTION PICTURE PRODUCTION AND ALLIED SERVICES
782	MOTION PICTURE DISTRIBUTION AND ALLIED SERVICES
783	MOTION PICTURE THEATERS
784	VIDEO TAPE RENTAL
791	DANCE STUDIOS, SCHOOLS, AND HALLS
792	THEATRICAL PRODUCERS (EXCEPT MOTION PICTURE), BANDS, ORCHESTRAS, AND ENTERTAINER
793	BOWLING CENTERS
794	COMMERCIAL SPORTS
799	MISCELLANEOUS AMUSEMENT AND RECREATION SERVICES
801	OFFICES AND CLINICS OF DOCTORS OF MEDICINE
802	OFFICES AND CLINICS OF DENTISTS
803	OFFICES AND CLINICS OF DOCTORS OF OSTEOPATHY
804	OFFICES AND CLINICS OF OTHER HEALTH PRACTITIONERS
805	NURSING AND PERSONAL CARE FACILITIES
806	HOSPITALS
807	MEDICAL AND DENTAL LABORATORIES
808	HOME HEALTH CARE SERVICES
809	MISCELLANEOUS HEALTH AND ALLIED SERVICES, NOT ELSEWHERE CLASSIFIED
811	LEGAL SERVICES
821	ELEMENTARY AND SECONDARY SCHOOLS
822	COLLEGES, UNIVERSITIES, PROFESSIONAL SCHOOLS, AND JUNIOR COLLEGES
823	LIBRARIES
824	VOCATIONAL SCHOOLS
829	SCHOOLS AND EDUCATIONAL SERVICES, NOT ELSEWHERE CLASSIFIED
832	INDIVIDUAL AND FAMILY SOCIAL SERVICES
833	JOB TRAINING AND VOCATIONAL REHABILITATION SERVICES
835	CHILD DAY CARE SERVICES
836	RESIDENTIAL CARE

SIC Code	Description
839	SOCIAL SERVICES, NOT ELSEWHERE CLASSIFIED
841	MUSEUMS AND ART GALLERIES
842	ARBORETA AND BOTANICAL OR ZOOLOGICAL GARDENS
861	BUSINESS ASSOCIATIONS
862	PROFESSIONAL MEMBERSHIP ORGANIZATIONS
863	LABOR UNIONS AND SIMILAR LABOR ORGANIZATIONS
864	CIVIC, SOCIAL, AND FRATERNAL ASSOCIATIONS
865	POLITICAL ORGANIZATIONS
866	RELIGIOUS ORGANIZATIONS
869	MEMBERSHIP ORGANIZATIONS, NOT ELSEWHERE CLASSIFIED
871	ENGINEERING, ARCHITECTURAL, AND SURVEYING SERVICES
872	ACCOUNTING, AUDITING, AND BOOKKEEPING SERVICES
873	RESEARCH, DEVELOPMENT, AND TESTING SERVICES
874	MANAGEMENT AND PUBLIC RELATIONS SERVICES
881	PRIVATE HOUSEHOLDS
899	SERVICES, NOT ELSEWHERE CLASSIFIED
911	EXECUTIVE OFFICES
912	LEGISLATIVE BODIES
913	EXECUTIVE AND LEGISLATIVE OFFICES COMBINED
919	GENERAL GOVERNMENT, NOT ELSEWHERE CLASSIFIED
921	COURTS
922	PUBLIC ORDER AND SAFETY
931	PUBLIC FINANCE, TAXATION, AND MONETARY POLICY
941	ADMINISTRATION OF EDUCATIONAL PROGRAMS
943	ADMINISTRATION OF PUBLIC HEALTH PROGRAMS
944	ADMINISTRATION OF SOCIAL, HUMAN RESOURCE AND INCOME MAINTENANCE PROGRAMS
945	ADMINISTRATION OF VETERANS' AFFAIRS, EXCEPT HEALTH AND INSURANCE
951	ADMINISTRATION OF ENVIRONMENTAL QUALITY PROGRAMS
953	ADMINISTRATION OF HOUSING AND URBAN DEVELOPMENT PROGRAMS
961	ADMINISTRATION OF GENERAL ECONOMIC PROGRAMS
962	REGULATION AND ADMINISTRATION OF TRANSPORTATION PROGRAMS
963	REGULATION AND ADMINISTRATION OF COMMUNICATIONS, ELECTRIC, GAS, AND OTHER UTILIT

SIC Code	Description
964	REGULATION OF AGRICULTURAL MARKETING AND COMMODITIES
965	REGULATION, LICENSING, AND INSPECTION OF MISCELLANEOUS COMMERCIAL SECTORS
966	SPACE RESEARCH AND TECHNOLOGY
971	NATIONAL SECURITY
972	INTERNATIONAL AFFAIRS
999	NONCLASSIFIABLE ESTABLISHMENTS

NBI PIER Project Element 4 Integrated Energy Systems, Productivity, and Building Science for Small Commercial HVAC Systems

Onsite Surveyor Training
Boulder Colorado
September 5, 2001

Outline

- Project Overview
- On-site Survey
- One-time Measurements
- Short-term Monitoring
- Model Calibration

Project Overview

Premise:

- Opportunity exists to improve the as-installed efficiency of small packaged systems
- Improvements will allow systems to perform to full potential

Program Objectives

- *Increase energy efficiency of small systems by 10%*
- *Small systems defined as packaged rooftop units <= 10 ton*
- *Identify strategies to solve inefficiency problems*
  - **System/building Design**
  - **Product Design**
  - **Installation**
  - **O&M**
  - **Codes**

Pro-Forma Problem List

- Economizers
- Fan controls
- Sizing
- Distribution efficiency
- Condensing temperature
- Tstat location/zoning
- Refrigerant charge
- Air flow

Potential Research Questions

- Fan controls
  - *What are the operating strategies?*
  - *Do they meet Title 24?*
  - *What are the IAQ implications?*
- Economizers
  - *How long do they last?*
  - *What are the major faults?*
    - *Linkages*
    - *Sensor locations*
    - *Dampers*
    - *Installation*

Potential Research Questions

- Thermostats
  - *What setback strategies are used?*
  - *Is thermostat in compliance with Title 24?*
  - *Is the location appropriate?*
- System sizing
  - *How was system sized?*
  - *Is sizing appropriate?*
- Duct leakage
  - *Are the ducts in a conditioned space?*
  - *What is the leakage percentage?*
  - *What is the leakage location?*

Potential Research Questions

- Condensing temperature
  - *How does unit condensing temp compare to ambient temp*
  - *What is the impact of a low albedo (cool) roof?*

Program tasks

- Project Planning and Management
- Market Advisors
- Background Research
- Field Surveys
- Analysis
- Building Science Solutions
- Design Guidelines
- Final Report

Market Advisors

- *Form technical advisors group (TAG)*
  - Assist research planning
  - Review results during implementation phase
  - Help define research products
- *Evaluate market response*
  - interviews
  - focus groups
  - case studies
  - demonstrations
- *Identify remaining non-technical market barriers*

Background Research

- *Building types with small HVAC systems*
- *Most common types of small commercial HVAC systems*
- *Investigate energy use by small commercial HVAC systems in California*
- *Identify designers of these systems*
- *Identify potential systems integration problems*
- *Identify causes of potential system integration problems*
- *Define population*

Field Surveys

- *Obtain data on Population*
- *Stratify Population*
- *Select Sample*
- *Recruit Sites*
- *Survey Methodology and Instruments*
- *Conduct Field Survey and short-term monitoring*
- *Analyze short-term data to I.D. faults*
- *Characterize field conditions*

Analysis

- *Investigate the factors contributing to failure or sub-optimum performance*
- *Develop computer models for each surveyed building*
- *Calibrate the models with utility and/or short-term measured data*
- *Use the model to analyze faults and determine lost savings*
- *Expand Data to Population*

Building Science Solutions

- *Link the failure modes to contributing factors*
- *Explore building science solutions for each mode of failure (assume 10 primary modes)*
  - *Design practice, such as "rules of thumb"*
  - *Component Specifications*
  - *Construction practices*
  - *Maintenance and operations*
  - *Equipment design*
  - *Financing*
  - *Occupancy*
- *Select one or two practical and cost-effective solutions for each mode of failure.*

Design Guidelines

- *Specify target audiences for market transformation activities*
- *Develop design guidelines to address each failure mode*
- *Propose design guidelines for system design, construction, integration, commissioning, maintenance and operations*
- *Propose improvements to codes and standards*

Schedule

Project/ Task Number	Task Name	Deliverable Number	Deliverable(s)	Accel.* Start Date	Accel.* Completion Date
4.1	**Project Planning and Management**				
4.1.1	Program Kickoff Meeting	4.1.1	• Meeting notes and summary	TBA	19-Jul-00
4.1.2	Project Review Meetings with CEC	4.1.2	• Meeting notes and summary	Periodic	
4.2	**Technical and Market Advisors**				
		4.2.1	• Suggested list of TAG members in year 1	2-Apr-01	15-May-01
		4.2.2	• Form TAG in year 2 (accelerate to year 1)	2-Apr-01	1-Jun-01
		4.2.3	• Report on initial meeting·	1-Jul-01	1-Aug-01
		4.2.4	• Meetings minutes and summary	1-Aug-01	1-Aug-03
4.3	**Background Research**				
		4.3.1	• Summary of background research results	1-Apr-01	1-Aug-01
		4.3.2	• List of system integration research issues to be addressed	1-May-01	1-Aug-01
4.4	**Field Surveys**				
		4.4.1	• Description of the field methods.	1-May-01	1-Aug-01
		4.4.2	• Survey method and questionnaires	1-Jun-01	1-Aug-01
		4.4.3	• Database of compiled information from the field surveys.	1-Jul-01	1-Feb-02
4.5	**Analysis and Statewide Estimates**				
		4.5.1	• Report on underlying causes of faults or sub-optimum performance in each building.	1-Nov-01	1-Jun-02
		4.5.2	• Results from computer models for each building.	1-Nov-01	1-Jun-02
		4.5.3	• Results from expanding the faults to the statewide population of buildings.	1-Jun-02	1-Sep-02
4.6	**Building Science Solutions**				
		4.6.1	• Report describing the problems and their building science solutions	1-Mar-02	1-Dec-02
4.7	**Design and Integration Solutions**				
		4.7.1	• Draft Design Guidelines for approval.	1-Jun-02	1-Sep-02
		4.7.2	• Proposed Design guidelines for specific organizations	1-Jun-02	1-Dec-02
		4.7.3	• Draft proposed improvements to codes and standards for approval	1-Jun-02	1-Dec-02
		4.7.4	• Draft Final Design Guidelines for approval	1-Sep-02	1-Dec-02
		4.7.5	• Final Design Guidelines	1-Dec-02	1-Feb-03
		4.7.6	• Final Proposed improvements to codes and standards for approval	1-Dec-02	1-Feb-03
		4.7.7	• Final Proposed improvements to codes and standards	1-Dec-02	1-Feb-03

Background Research

Market Characteristics

- NRNC database and CEC new construction forecast used to develop market characteristics
  - *SF by building type*
  - *HVAC system by building type*
  - *Unit sizes by building type*
  - *Identify target population*

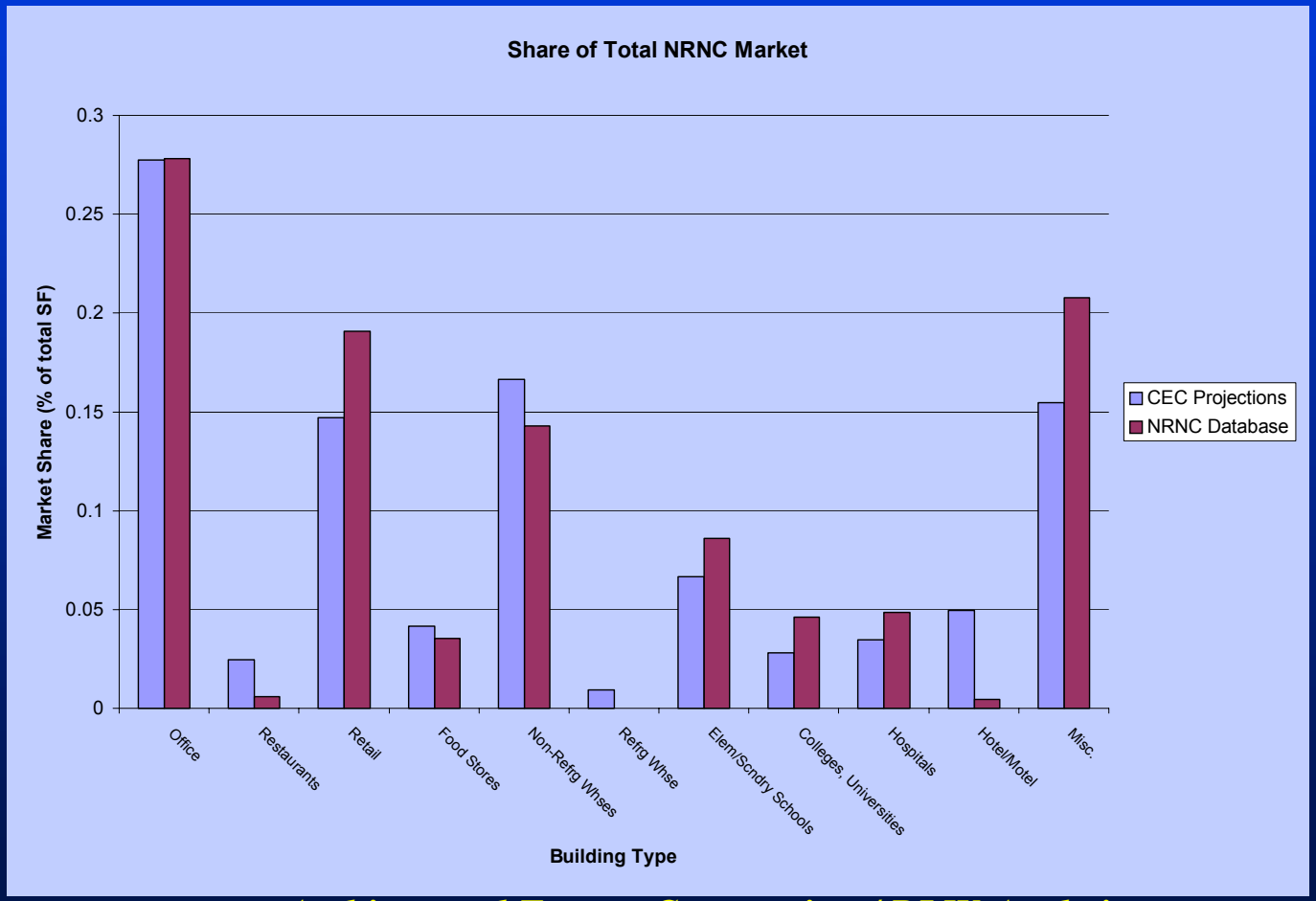
NRNC Database

- 990 individual buildings
  - *Statistically representative of CA NRNC*
- Onsite surveys primarily from NRNC DSM impact evaluations
  - *Participant and NP sites*
  - *Participants weighted to reflect population*
- Supplemental onsites conducted to improve coverage

Linkage to DOE-2

- Automated modeling software linked to database
- Creates DOE-2 models from building characteristics
- Automated parametric analysis
- Set up for batch processing

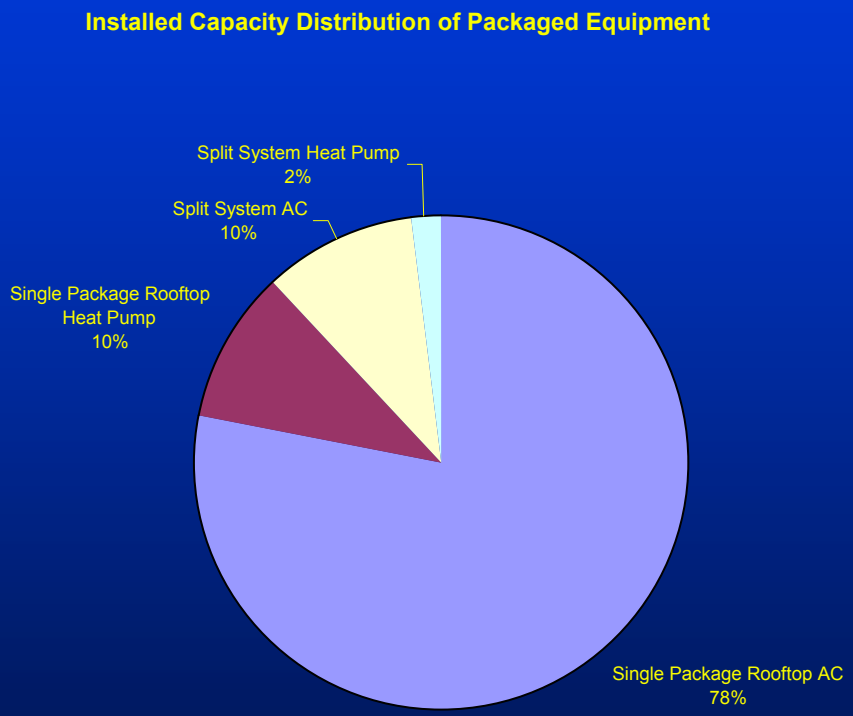
NRNC Database and CEC Projections



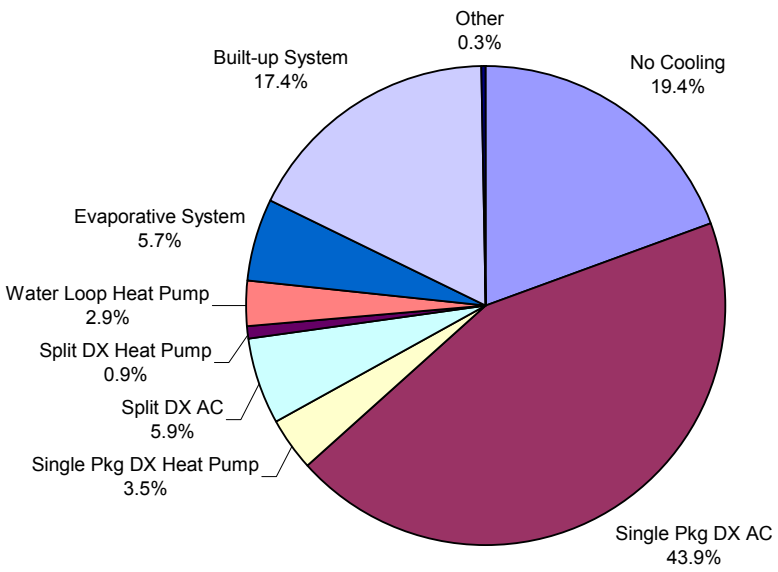
Market Characteristics

- Majority of cooling capacity is packaged equipment
- Most common cooling unit size is 10 ton
- Single package equipment is most popular small unit

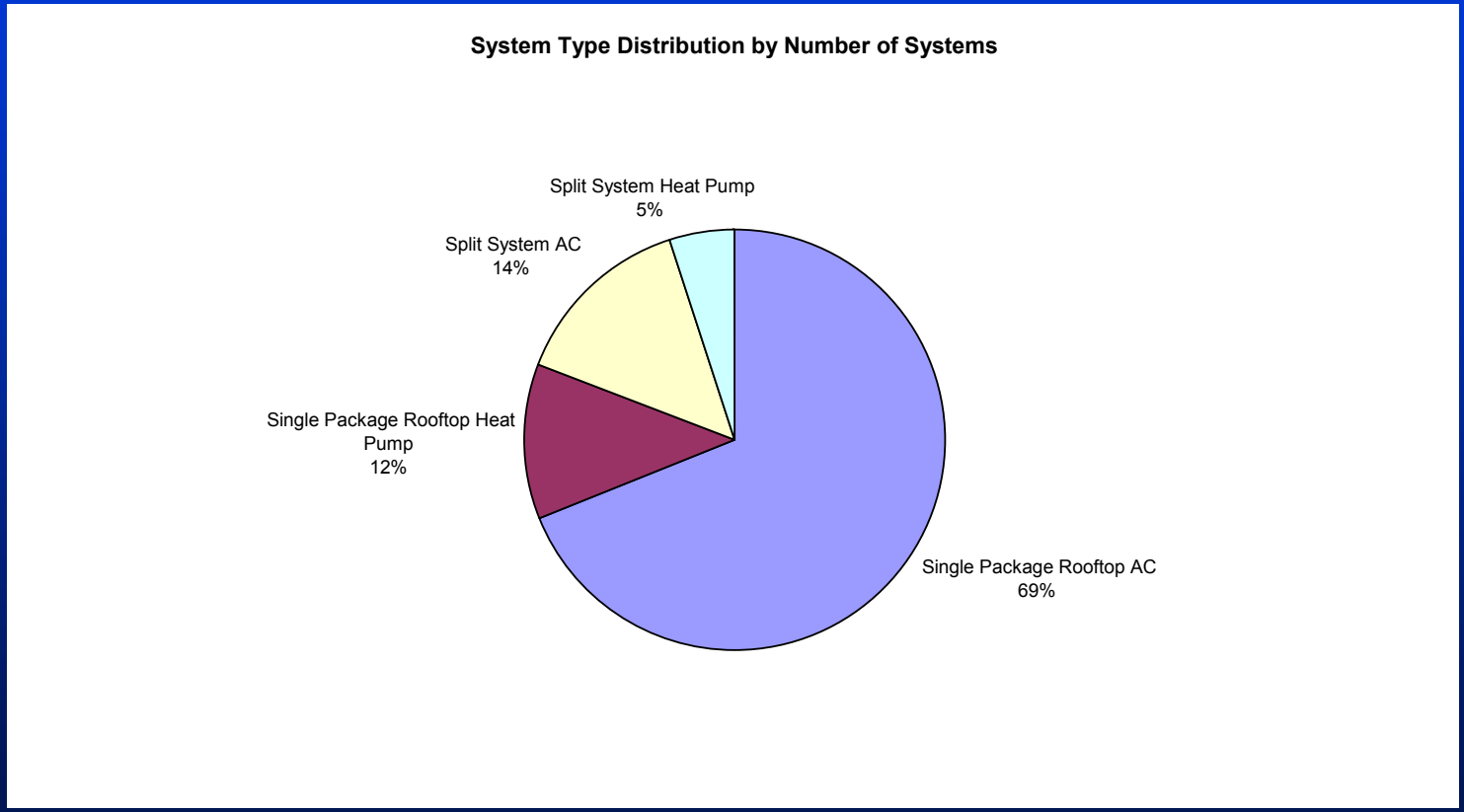
Unit Type Distribution



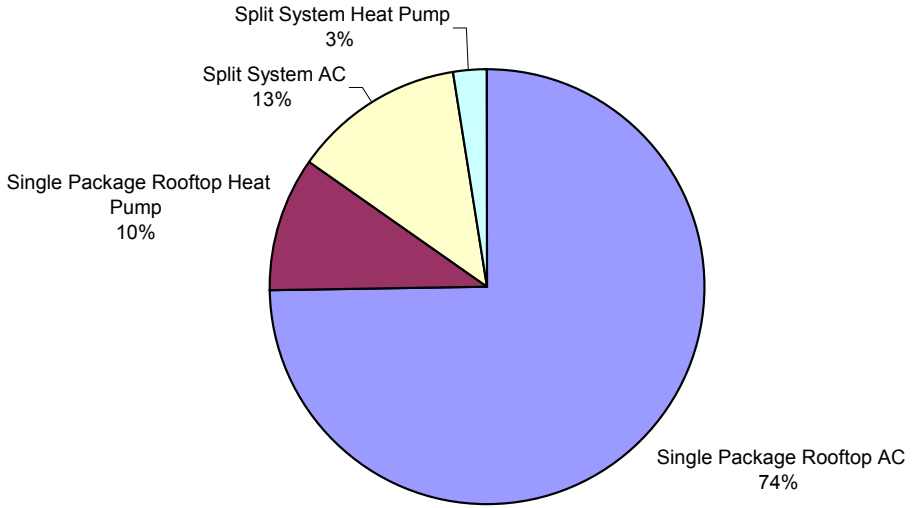
Market Characteristics



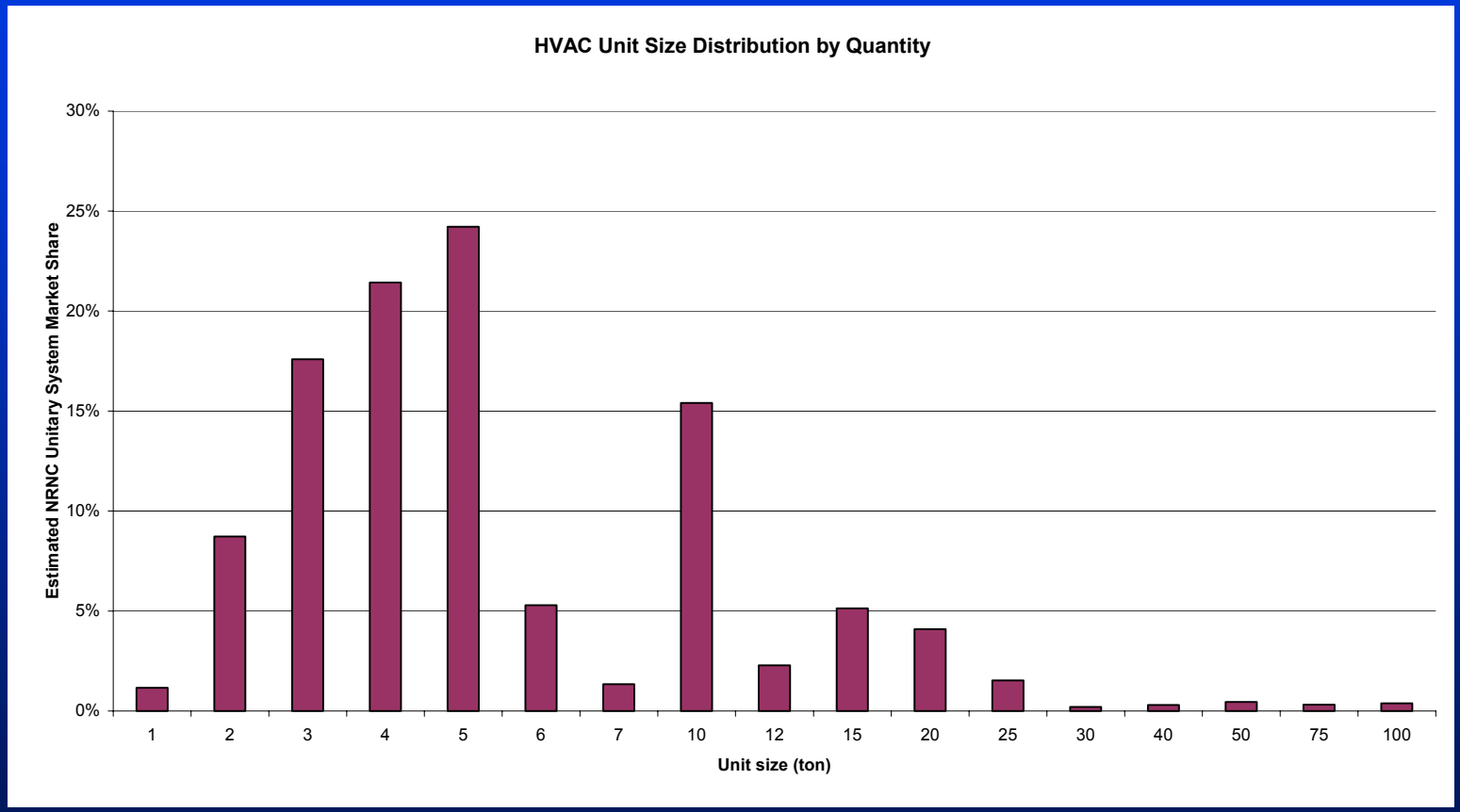
Market Characteristics



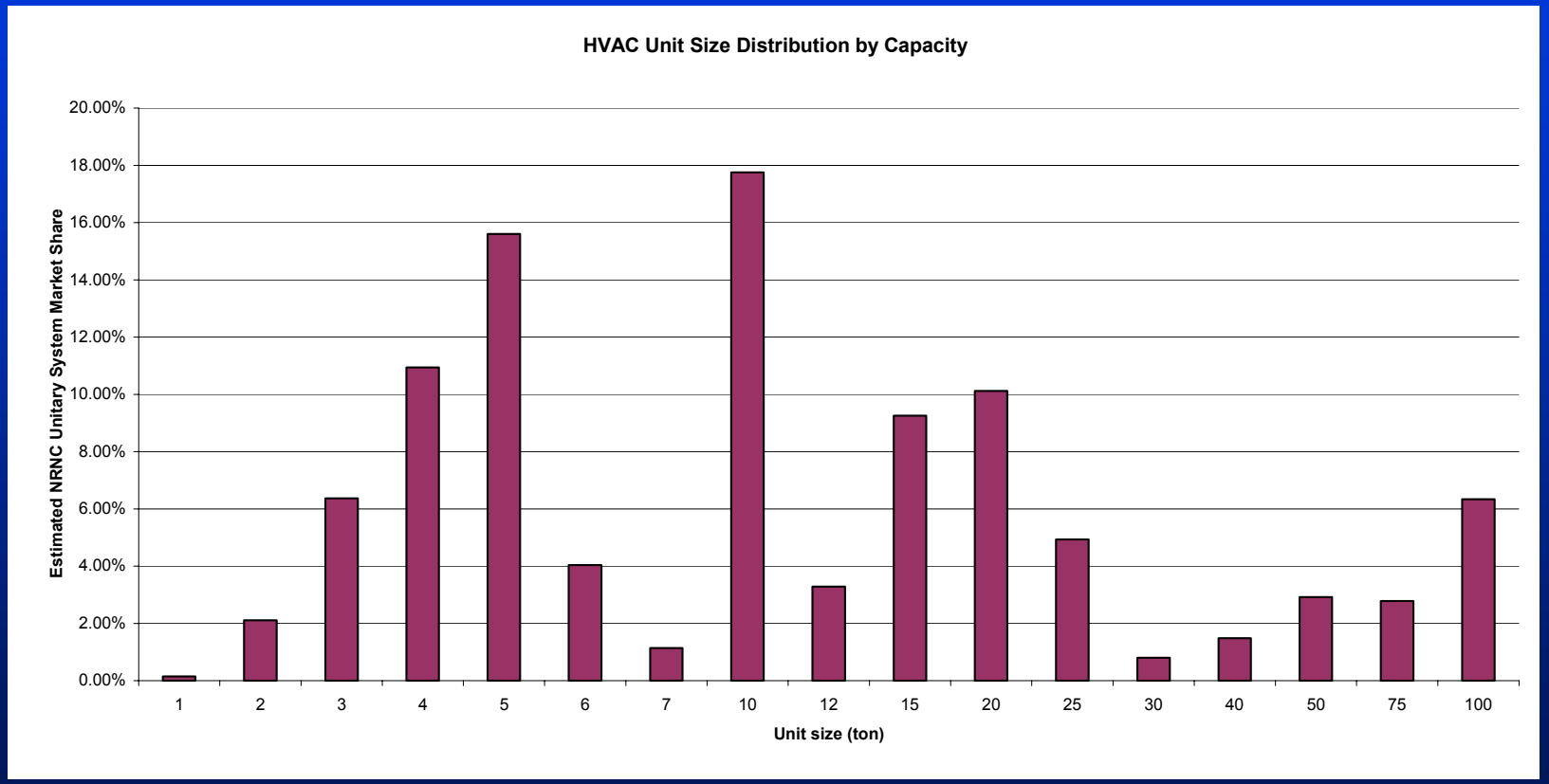
Market Characteristics



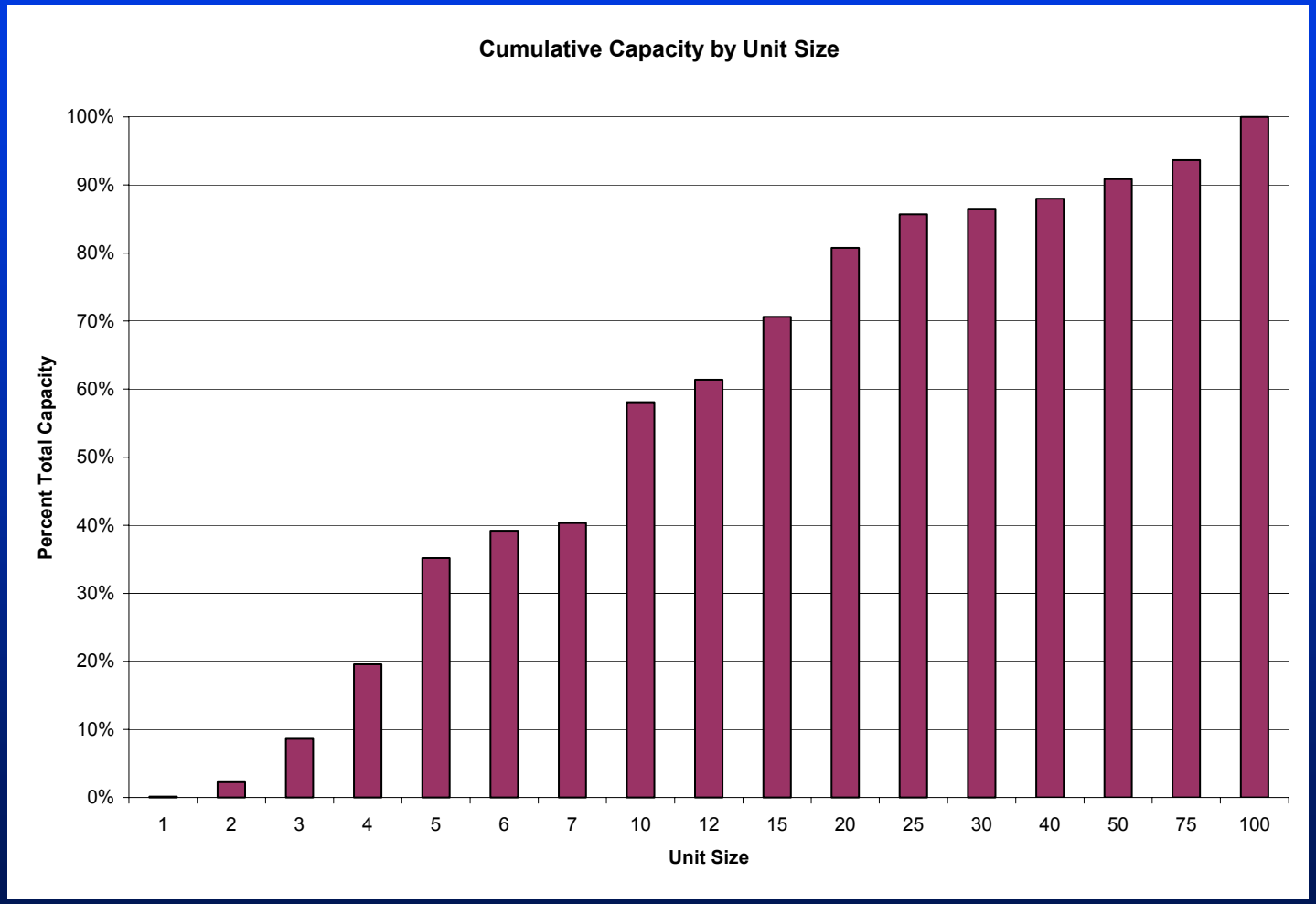
Market Characteristics



Market Characteristics



Market Characteristics



Relevant Research

- Commercial
  - *LBNL Duct leakage in small commercial buildings (Delp, et al.)*
  - *PG&E Economizer study (Feltz)*
  - *AEC in-house building diagnostics projects*
  - *NEES Commercial RTU Tune-up*
  - *Current Modera study for SCE*
  - *CEE Commercial Guidelines*
- Residential
  - *Duct leakage (Modera, Proctor)*
  - *Refrigerant charge (Proctor, Neal)*
  - *Air flow(Proctor, Neal, FSEC)*

Field Activities

Sample selection

- Challenges:
  - *Fairly specific target population*
  - *Site contacts may not be knowledgeable*

Data collection

- Whole-building survey
- Equipment inspections
  - *Economizer operation*
  - *Duct system location relative to insulation*
- One-time tests
  - *Refrigerant Charge*
  - *Duct leakage/Air flow*
- Short-term monitoring
  - *fan controls*
  - *economizer operation*
  - *equipment sizing*

Sample Design

- 82 total sites
- All sites:
  - *On-site survey*
  - *Equipment inspections*
  - *Short term monitoring*
- Subsample
  - *Refrigerant charge*
  - *Air flow and duct leakage*
- Make best use of resources for surveys, testing and modeling to answer questions

On-Site Surveys

- *ModelIT survey for DOE Model*
- *Occupant interviews*
  - Normal operations info
  - Probe comfort/IAQ/noise problems
  - Tstat use
- *Plan review*
  - Look for product substitutions and design changes

Short-Term Monitoring

- *Use AEC MicroDataLogger and Hobo*
- *Current, Tsup, Tmix, Tret,*
- *Global Tamb, Rooftop Temp*
- *Diffuser outlet measurements w/ Hobo*
- *Room temperature near thermostat w/ Hobo*
- *Set up project and visualize data using Enforma*
- *Calibrate models to STM data*

Economizer Testing

- *Observations:*
  - Minimum OA setpoint
  - Controller setpoint
  - Physical condition
- *Functional Test*
  - override controller to observe open/close cycle
  - simulate cool conditions; observe response
- *Plot STM data*
  - Tmix, Tamb, Tret

Refrigerant Charge Testing

- *Will sub out to CheckMe contractors*
- *Uses pressure and temperature measurements*
- *Can flag for high/low airflow*
- *Test a sub-sample of units*

Duct Leakage

- *Visual inspection to pre-screen sites*
  - supply/return location
    - conditioned vs unconditioned
  - identify major potential leakage sites
    - disconnected ducts
    - leaky cabinets
    - plenum infiltration
- *Quantitative testing on sample of screened sites*

Analysis and Impact Estimates

- *Impacts will be modeled and projected to population using NRNC database*
  - DOE-2 modeling software programmed to simulate impact of faults
- *DOE-2 models of all sites in NRNC database to project impacts to all buildings*
  - Field data used to estimate fraction of sites with problems
- *Calculate energy consumption, demand, cost, and ventilation impacts*

Analysis and Impact Estimates

- *DOE-2 Modeling Issues*
  - Performance curves for charge and air flow variations
  - Duct leakage modeling
    - LBL Pier project research

Impact Estimates

- *HVAC energy impacts*
  - Economizer - 5% to 50+%, depending on CTZ
  - Low air flow - 10%
  - Refrigerant charge 10% to 20%
  - Duct leakage ~ 25%
  - Fan controls (additional energy consumption - OA benefits only)
  - Sizing 10%

Data Products

- *Specify target audiences for research results*
  - System design
  - Equipment design
  - Construction
  - Commissioning
  - Operations and maintenance
- *Identify needs of audience*
- *Develop data products that meet the needs*

Data Products

- *Develop dissemination strategies*
  - Improvements to codes and standards
  - Design guidelines
  - Trade magazine articles
  - Utility programs
    - Energy Design Resources
    - Savings by Design
  - Others??

On-Site Survey

- Progression of survey process
  - *Interview*
  - *HVAC*
  - *Interior spaces*
  - *Equipment/space association*
- Fundamental Unit of Study is HVAC unit, not building.
- Select four units ten tons or smaller
  - *Skip units that are not used or used seldomly*
- Survey space served by these units

On-Site Survey

Interview Questions

- Identify building functional areas
  - *Areas = schedules!!*
- For each functional area, record
  - *Daily schedules for occupants, interior lighting, and equipment/plug loads*
  - *Daily schedules of kitchen equipment*
  - *Local HVAC control*
- Systems operations data
  - *HVAC*
  - *Refrigeration*
  - *Other miscellaneous*

Building Characteristics

- HVAC systems
  - *Make, model number from nameplate*
  - *Serial Number*
  - *OA controls*
  - *Duct system*
  - *Thermostats*

Building Characteristics

- Refrigeration
  - *Case/cooler inventory*
    - *Type, size, product*
    - *Condenser type (remote vs. integral)*

Building Characteristics

- Cooking equipment
  - *Cookline inventory*
    - *Type, size, fuel type*
  - *Hood inventory*
    - *Type, size, appliances served, fan power*

Building Characteristics

- Interior spaces
  - *Occupancy*
  - *Lighting*
  - *Plug and process loads*
- Shell
  - *Wall type, R-value, orientation*
  - *Window type, shading, orientation*

Component Relationships

- Associate areas and spaces
- Associate HVAC equipment and spaces
- Establish zoning
- Four zones, Four systems, One Unit/system

Areas, Spaces, Zones and Systems

- Area refers to schedules
- Space refers to interior floor space or rooms
  - *Defined by occupancy*
- Zone is a collection of spaces served by a system

Building Overview

- Identify building type and size
- Identify functional areas
- Areas are defined by schedules
  - *Example: Strip retail building*
    - *Insurance office 8am - 5pm*
    - *Retail store 10am - 9pm*
    - *Convenience grocery 24hr*
- Five areas max. per building

Schedules

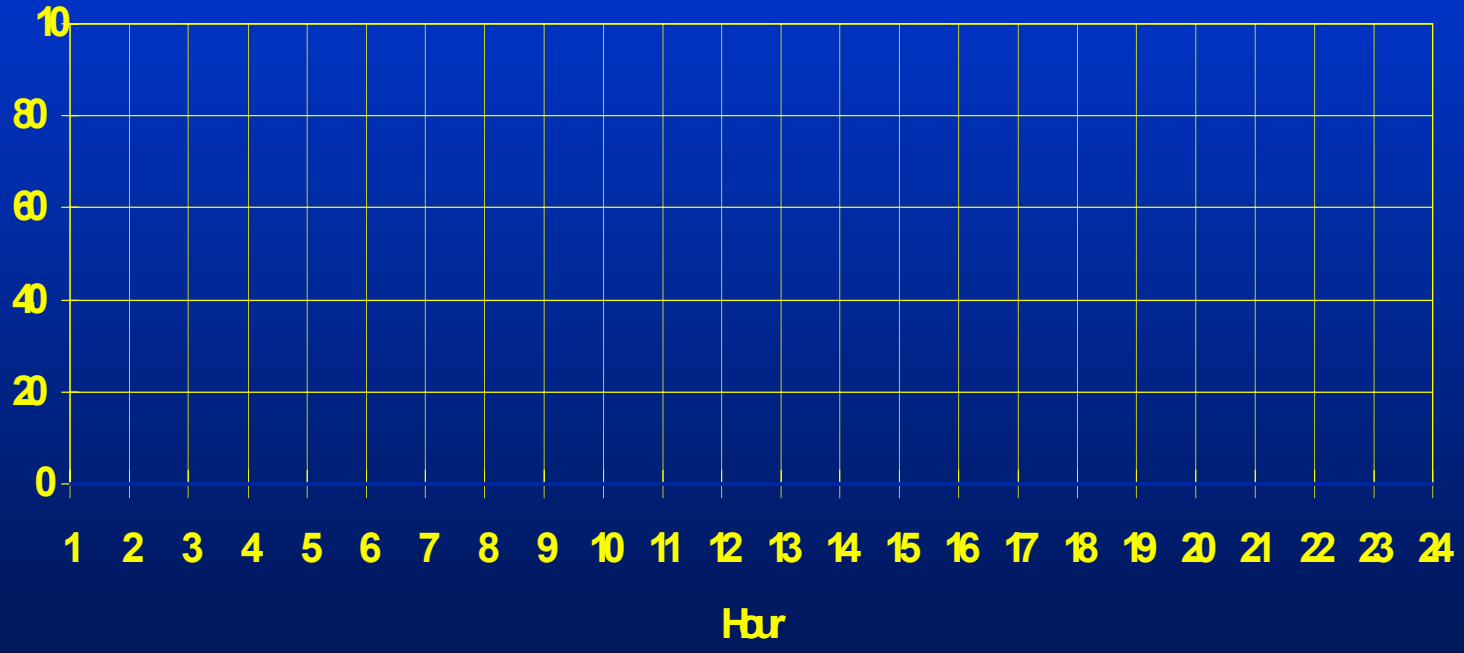
- A separate set of schedules is defined for each functional area
- Make duplicate pages - fill-out one set for each area
- Daytypes
  - *Full operation (normal workday)*
  - *Light operation (partial workday)*
  - *Closed*
  - *Assign to days of week*

Schedules

- Seasonal variation
  - *Covers monthly variability in scheduling*
  - *Used for schools, retail, etc.*
- Holidays
  - *indicate how many holidays are taken during Thanksgiving and Christmas*
- Occupancy, Lighting, Miscellaneous Equipment
  - *Hourly schedules by daytype*

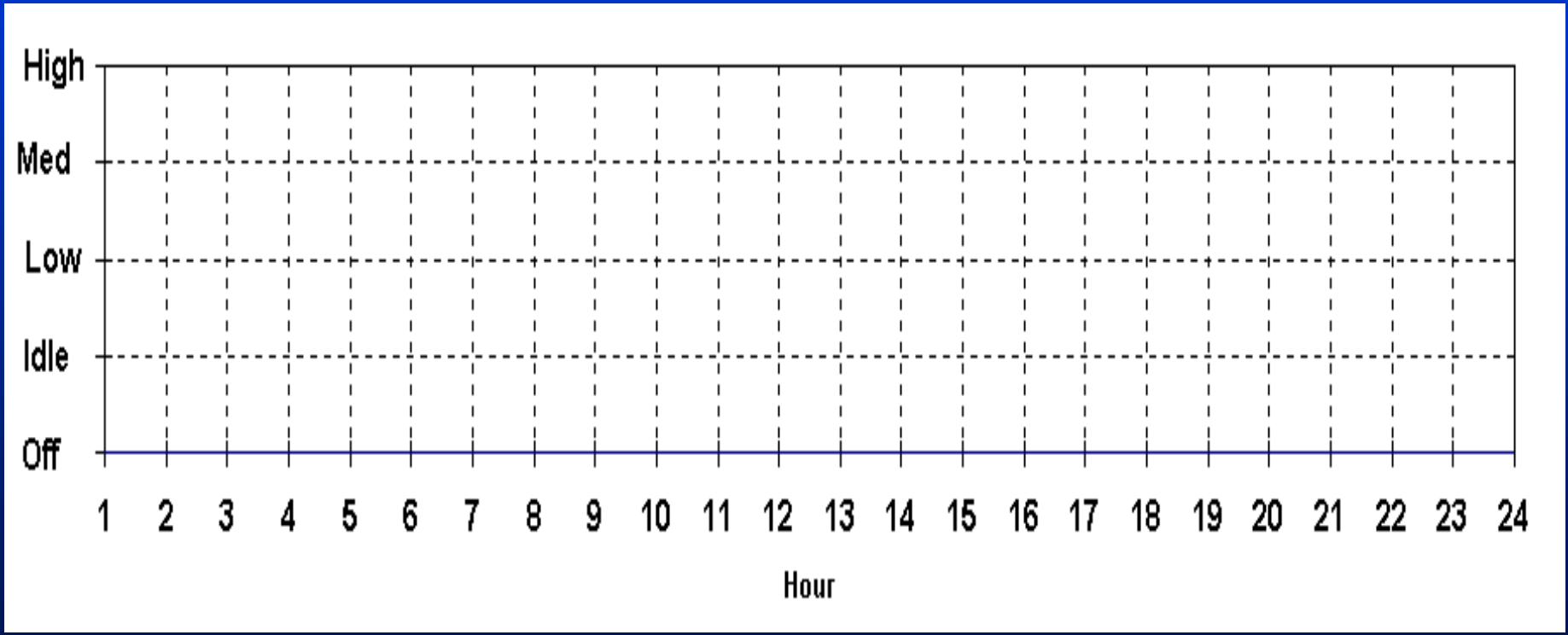
Schedules

- Graphical input - interpret to nearest 10 percent



Schedules

- Kitchen - discrete operating levels



Schedules

- Fan system

on																							
off																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Schedules

- Thermostat

Unocc CSP																							
Occ CSP																							
Occ HSP																							
Unocc HSP																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Packaged HVAC

- System types
  - *Single package AC and heat pump*
  - *Split system AC and heat pump*
- Not in scope:
  - *PTAC/PTHP*
  - *Window/wall units*
  - *Water loop heat pumps*
  - *Evaporative systems*

Packaged HVAC

- Most popular system
- Make, model and serial number are key field data
- Also survey thermostat make and model number
- ID situations contributing to high condenser or OA EAT:
  - *roof surface, parapet and/or screens, proximity to heat sources from adjacent units or exhausts*
- Observe adjacent tstat locations and setpoints
  - *Adjacent tstats*
  - *Poor location (drafts, heat sources, isolation from general room conditions)*

Packaged HVAC

- Observe economizer control settings
- Observe HVAC unit to curb installation conditions for obvious leakage
- Observe installation of economizer components
- Observe accessability of unit for maintenance
- Observe filter condition, cabinet condition

Duct Losses

- Location
  - *Plenum*
  - *Conditioned*
  - *Outside*
  - *Other (notes)*

Duct Losses

- Construction
  - *Sheet metal*
  - *Flex*
  - *Fiberglass*
  - *Ductboard*
  - *Other*
- R-value
- area

Plenum

- Under “Roof” Tab
- Roof U- or R-value
- Ceiling R-value
- Plenum wall R-value
- Plenum height
  - *Use average height for plenum wall losses*
- Indicate if return plenum

Exterior Surfaces

- Need U-value and HC for each opaque surface enclosing the zone
  - *Observe from plans or Title 24 ENV form*
  - *Calculated from wall type and R-value*
- Try to look at plans - tough to observe insulation R-values in the field
- Estimate gross height and width, and orientation of each surface enclosing the zone
  - *Check floor plans and elevations, bring an architects scale*
  - *Use a tape measure if necessary*
  - *Height and width are* **gross,** *including windows*

Windows

- Need U-value and shading coefficient (SC)
  - *Observe from Title 24 ENV form or plans*
  - *Measure glazing transmission*
- Estimate height and width and orientation of each window enclosing the zone
  - *Check floor plans and elevations, bring an architects scale*
  - *Use a tape measure if necessary*
- Observe interior and exterior shading
- Overhangs
  - *Offset is distance from top of window to bottom of overhang*
  - *Projection is distance from wall to edge of overhang*

Cool Roofs

- Roof color for cooling savings
  - *Roof "aged" reflectance (Cool Roof Rating Council)*
  - *Roof color (reflectance defaulted)*
- Survey material type and color

Space

- Space is the smallest unit of floor area surveyed
- Sometimes zones are too big to be surveyed efficiently
- Observe occupancy correctly - very important!!
- Estimate floor area, % corridor, restroom or support area
- Identify and count lighting fixtures and controls
- Survey plug loads
- Space multiplier can save time

Lighting

- Observe fixture type(s), enter a fixture code for each type observed in the space
- Count the fixtures - very important to get an accurate count!
- Identify lighting controls, and % of fixtures controlled

Miscellaneous Equipment and Plug Loads

- Try to get a good count, since surveyed area is small
- HVAC sizing is a key issue

Refrigeration

- Survey refrigerated cases in grocery stores and kitchens
- Compressors may be integral or external
  - *Integral compressor/condenser = plug load*
- Major influence on load in groceries

Refrigerated Cases

- Survey by case type and product displayed
  - *Product code determines temperature*
- Units of measure vary by case type
- Walk-in/reach-in -survey floor area and number of doors
- Walk-in - survey floor area
- Closed cases - look a number of glazing panes

Foodservice Equipment

- Cookline
  - *Survey both electric and gas equipment*
  - *Trade sizes can be used of nameplates are not accessible*
  - *Indicate if under a hood*
- Hoods
  - *Need CFM and fan hp*
  - *Will be calculated from size (face area) if necessary*
  - *Indicate if makeup air is conditioned*

Component Relationships

- Zoning
  - *Unusual internal gains*
  - *Operating schedules*
  - *Follow HVAC zoning*
- HVAC system/zone association checklist
  - *Assemble inventoried HVAC components into a system*
  - *Assign systems to zones served*
- Functional area/zone association checklist
- Space/zone association checklist

System/Zone Association Checklist

- Very important - builds the model from the various "pieces" surveyed
- Systems are DOE-2 "virtual" system; should be one unit/system
- All equipment and zones surveyed must be accounted for
- Zone can't be served by more than one system

Area/Zone and Space Association Checklists

- Area/Zone Association
  - *Attaches schedules (areas) to zones*
  - *Only one area/zone*
  - *All defined areas must be associated to a zone, and vice versa*
- Space/Zone Association
  - *Aggregates spaces into zones*
  - *Only one zone per space*
  - *All spaces and zones must be accounted for*

Spot Watt Measurements

- Fan only
- Fan plus compressors
- ID legs with fan motor
- Measure kW, PF, amps on all three phases
- Use Fluke meter

STM

- *Compare ambient temp, condenser or OA EAT to design temp*
- *ID fan operating schedule, compare with building schedule*
- *Measure condenser or OA EAT.*
- *Set up ambient station to measure ambient temp and RH*
- *Observe economizer operation, look for faults*

STM

- *Observe HVAC system operation for evidence of oversizing*
- *Review time series plots of heating and cooling on adjacent units*

Mfg Lit review

- *Check cooling capacity*
- *Check economizer installation instructions for major components*
- *Compare factory recommendations to Title 24 requirements*
- *Get manufacturer recommendations on installation procedures*
- *Identify unit mounting and curb sealing requirements*

Mfg Lit review

- *Review installation instructions*
- *Review thermostat fan control capabilities*

- *See if economizer is available as a factory option*

Building Plans and Title 24 Docs

- *Check duct system location relative to conditioned and unconditioned space; compare to as-built*
- *Check HVAC unit cooling capacity and sizing calculations*
- *Compare field-installed unit with unit shown on plans*
  ID tstat unit spec
- *Look for specs on duct installation standards*
- *Record fan power, CFM and ESP from mechanical equipment schedule*

General Information

Site ID # ☐

Surveyor Name: Building Name:

Date: Primary Contact: Phone:

Building Address:

City Zip

Start Time: Finish Time:

Interview Questions

The following interview questions will be used to help us identify unobservable aspects of your building. These aspects include occupancy history, schedules, and heating and cooling controls. Answers to these questions will be coupled with data collected from our walk-through audit to produce a computer model which simulates the annual energy use of the building.

Building Overview

Q1. What is the overall floor area affected by the new construction/remodeling/renovation at the site?

_____. Compare this value to the square footage value located on the "On-Site Form". Please comment on any discrepancies below.

_____
_____
_____
_____
___

Q2. What is the floor area served by small HVAC units?

- ❑ same as overall building floor area
- ❑ _____SF

Q3. How many floors? _____

Q4. Characterize the site by circling the appropriate description:

1. New building ("green field")
2. Alteration of existing building
3. Addition to existing building
4. Alteration of existing building and addition to existing building

Q5. Circle the appropriate building type description:

1	Large office	11	Hospital
2	Small office	12	Medical Clinic
3	Restaurants	13	Hotel/Motel
4	Large retail	14	Miscellaneous
5	Small Retail		
6	Food Stores		
7	Refrigerated Warehouse		
8	Non-Refrigerated Warehouse		
9	Elementry / Secondary School		
10	College / University		

Building Areas

Q6. Which statement best describes the operation of the building?

( ) The entire building operates on *basically* the same schedule
( ) There are areas of the building (departments, tenants, etc.) that have *substantially* different operating schedules

Q7. If different areas of the building (departments, tenants, etc.) have *substantially* different operational schedules, divide the building into up to five areas with differing schedules, and provide a name for each area:

1. _____

2. _____

3. _____

4. _____

5. _____

Notes:

❑ **Building-Wide** **- or -** (fill out only one page)	**Area #___ and Area Name _____** (fill out one page per area)

Schedules

The following questions will help us establish schedules for the building.

Q8. What would be the best way to group the days of the week to describe the operation of this area? One of the three operation levels must be assigned to each day of the week.

	M	Tu	W	Th	F	Sa	Su	Holiday
Full operation:	❑	❑	❑	❑	❑	❑	❑	❑
Light operation:	❑	❑	❑	❑	❑	❑	❑	❑
Closed:	❑	❑	❑	❑	❑	❑	❑	❑

Q9. Are there any months that this area has higher or lower than normal operating hours? Indicate months of increased or decreased operating hours. Normal (100%) is assumed for blank entries.

	Lighting % of Normal	HVAC % of Normal	Equip and Process % of Normal
Jan	____%	____%	____%
Feb	____%	____%	____%
Mar	____%	____%	____%
Apr	____%	____%	____%
May	____%	____%	____%
Jun	____%	____%	____%
Jul	____%	____%	____%
Aug	____%	____%	____%
Sep	____%	____%	____%
Oct	____%	____%	____%
Nov	____%	____%	____%
Dec	____%	____%	____%

Q10. Which holidays are observed (check all that apply)

❑ New Years day ❑ MLK day ❑ Presidents' day ❑ Easter _____ days

❑ Memorial day ❑ July 4th ❑ Labor day ❑ Columbus day

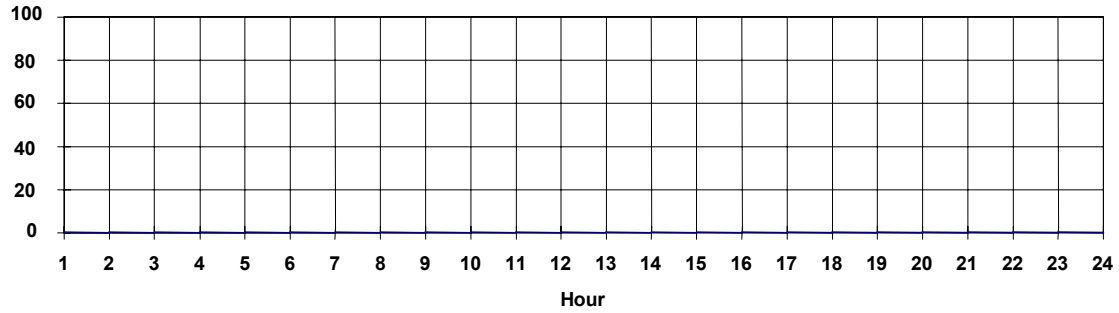
❑ Veteran's day ❑ Thanksgiving ____ days ❑ Christmas _____ days

Note: Holidays for 2001

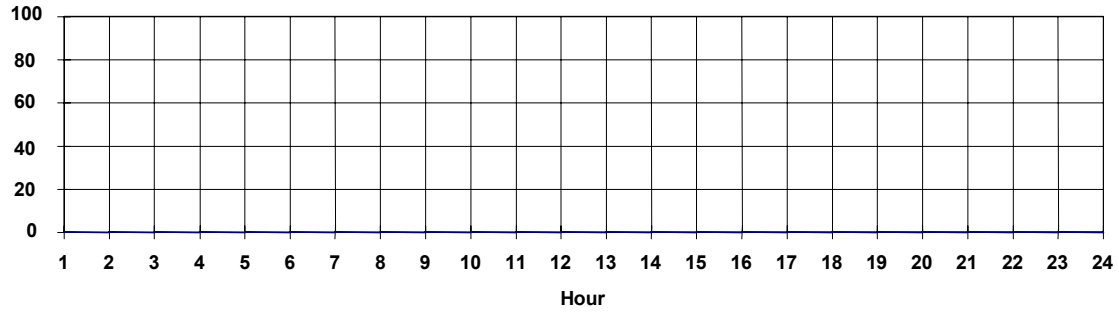
Holiday	Day/Date	Holiday	Day/Date
New Years day	Mon Jan 1	Labor day	Mon Sep 3
MLK day	Mon Jan 15	Columbus day	Mon Oct 8
Presidents' day	Mon Feb 19	Veteran's day	Sun Nov 11
Easter	Sun Apr 15	Thanksgiving	Thur Nov 22
Memorial day	Mon May 28	Christmas	Tue Dec 25
July 4th	Wed Jul 4		

❑ **Building-Wide** **- or -**	**Area #___ and Area Name _____**
(fill out only one page)	(fill out one page per area)

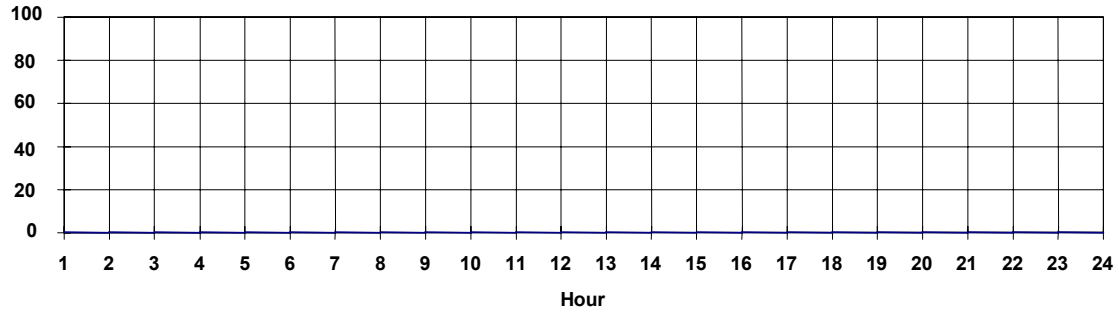
Q11. Draw a line that describes the ***occupancy*** schedule for a ***full operation day***.



Q12. Draw a line that describes the ***occupancy*** schedule for a ***light operation day***.

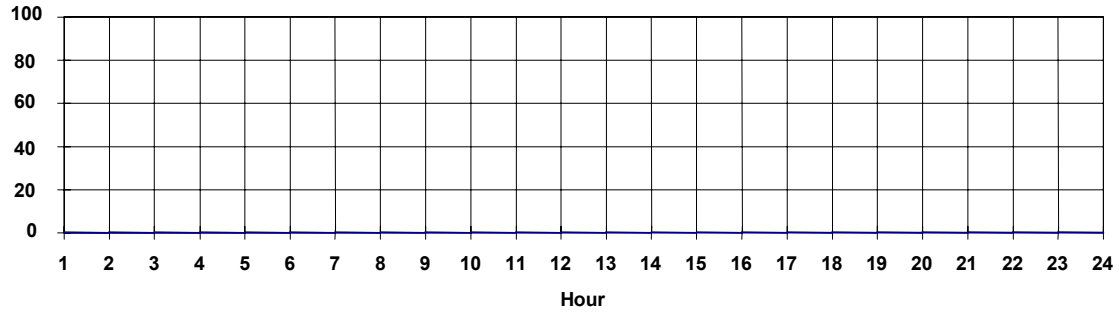


Q13. Draw a line that describes the ***occupancy*** schedule for a ***closed operation day***.

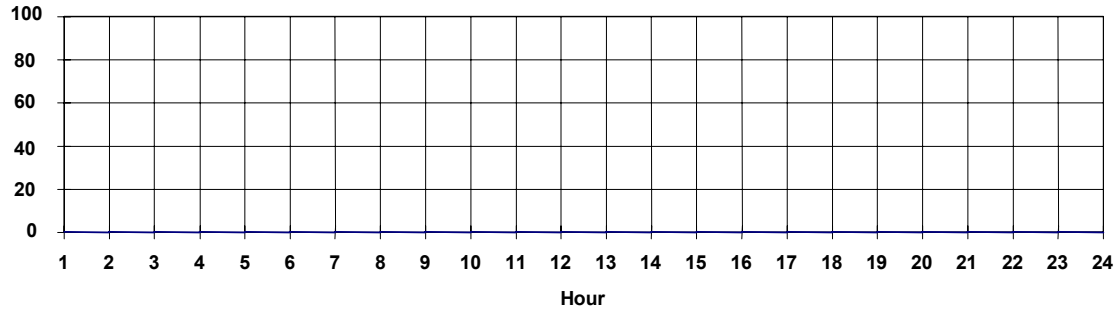


❑ **Building-Wide** **- or -**	**Area #___ and Area Name _____**
(fill out only one page)	(fill out one page per area)

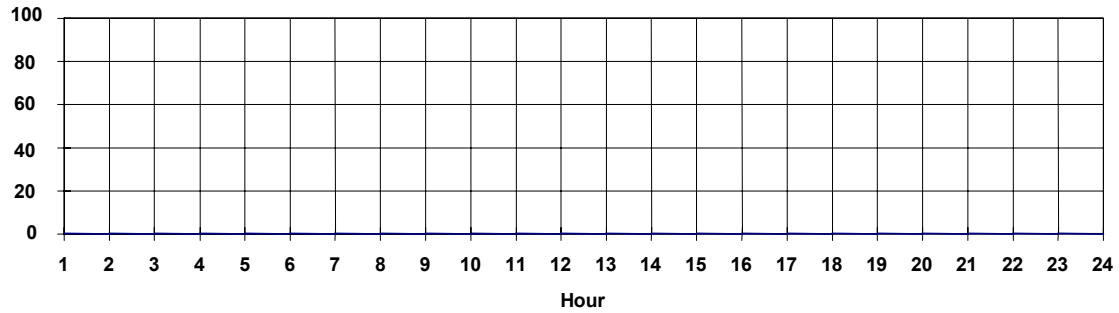
Q14. Draw a line that describes the schedule of use for ***interior lighting*** for a ***full operation day***.



Q15. Draw a line that describes the schedule of use for ***interior lighting*** for a ***light operation day***.



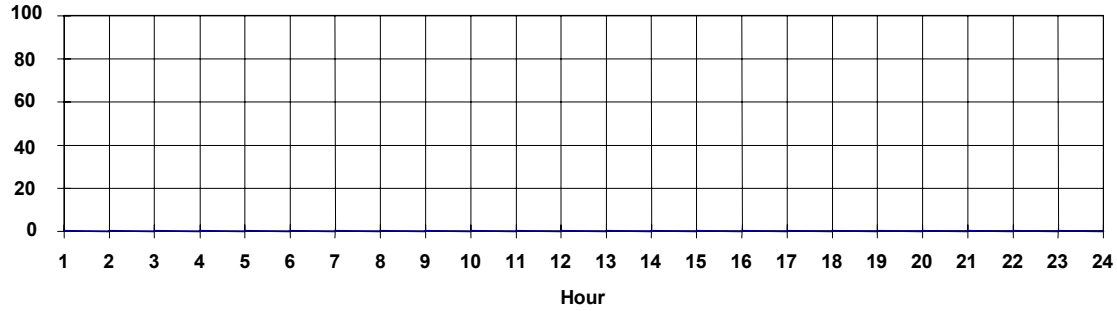
Q16. Draw a line that describes the schedule of use for ***interior lighting*** for a ***closed operation day***.



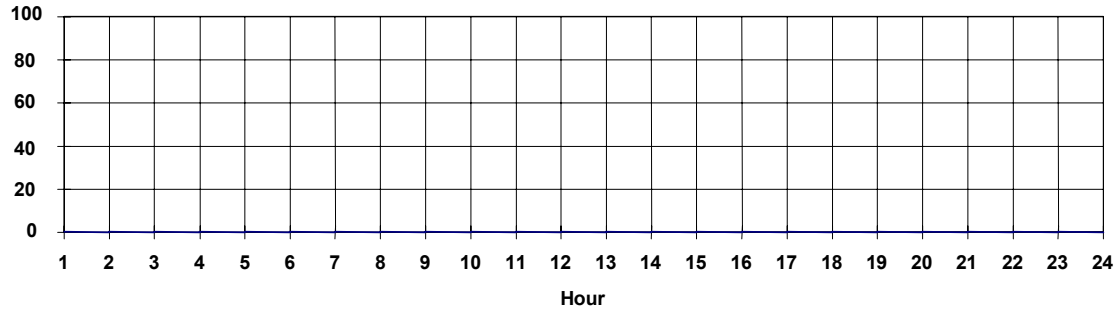
❑ **Building-Wide** **- or -**	**Area #___ and Area Name _____**
(fill out only one page)	(fill out one page per area)

Miscellaneous equipment and plug loads refer to any electrical equipment located in the conditioned space which is not lighting or HVAC

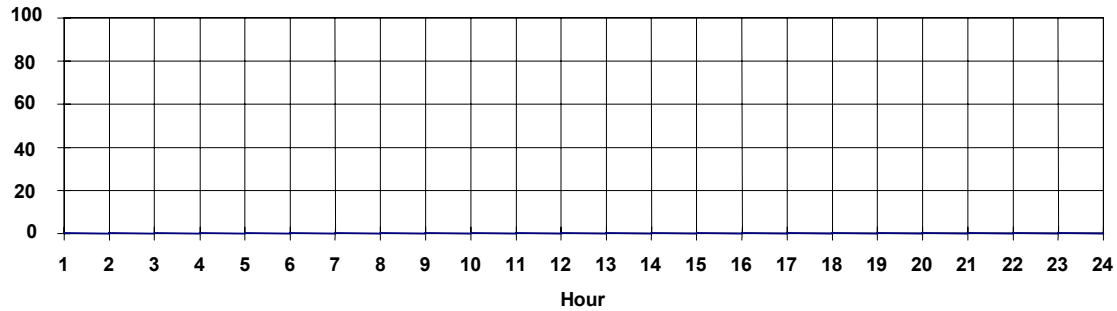
Q17. Draw a line that describes the schedule of use for ***miscellaneous equipment and plug loads*** for a ***full operation day***.



Q18. Draw a line that describes the schedule of use for ***miscellaneous equipment and plug loads*** for a ***light operation day***.



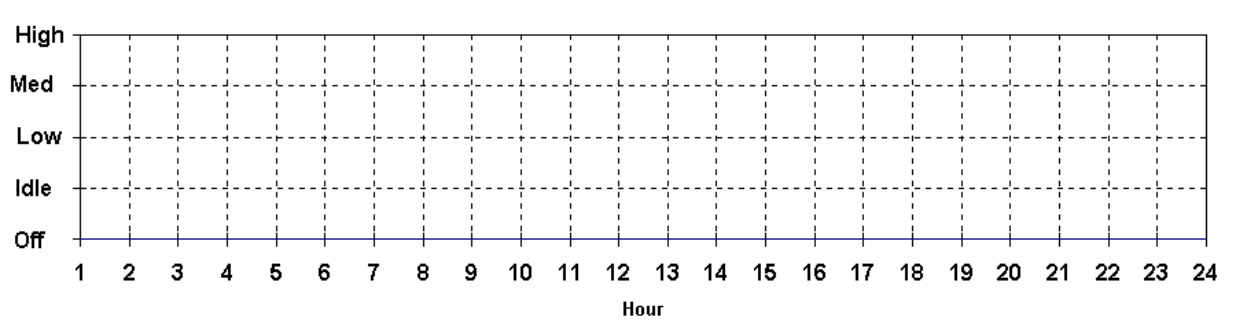
Q19. Draw a line that describes the schedule of use for ***miscellaneous equipment and plug loads*** for a ***closed operation day***.



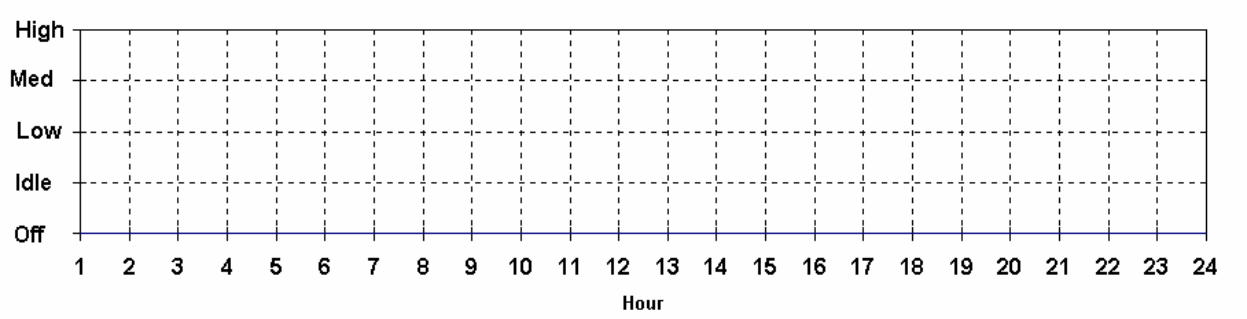
❑ **Building-Wide** **- or -**	**Area #___ and Area Name _____**
(fill out only one page)	(fill out one page per area)

Kitchen Operation

Q20. If the area has a commercial kitchen, draw a line that describes the schedule of use for ***kitchen equipment*** for a ***full operation day***.



Q21. If the area has a commercial kitchen, draw a line that describes the schedule of use for ***kitchen equipment*** for a ***light operation day***.



❑ **Building-Wide** **- or -** (fill out only one page)	**Area #___ and Area Name _____** (fill out one page per area)

Room Thermostat Setpoints

Q22. Enter the values for heating and cooling thermostat setpoints during normal (occupied) and setback (unoccupied) periods

Period	**Heating Setpoint**	**Cooling Setpoint**
Occupied		
Unoccupied		

Set CSP to 99 for "off," set the HSP to 45 for "off"

Q23. Who is responsible for thermostat setpoint maintenance?

❑ Occupants ❑ Management ❑ HVAC service company

❑ Other (list) _____

Q24. Are room temperatures in this area controlled by the building EMS? Y N DK

Q25. Does the setback schedule in this area follow the fan on/off schedule? Y N DK

If the answer is N or DK, define the setback schedule below:

Q26. Draw a line that defines the occupied and unoccupied mode for a ***full operation day***. DK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupied																								
Unoccupied																								

Q27. Draw a line that defines the occupied and unoccupied mode for a ***light operation day***. DK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupied																								
Unoccupied																								

Q28. Draw a line that defines the occupied and unoccupied mode for a ***closed operation day***. DK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Occupied																								
Unoccupied																								

HVAC Fan System Operation

This section is used to establish the fan system schedule. List the hours that the fans are "on" or "off." "On" indicates occupied mode, where the fans run continuously. "Off" indicates unoccupied mode, where the fans cycle on only if needed to satisfy space temperature needs, or are shut off regardless of space temperature..

Q29. Draw a line that describes the fan system operation for a ***full operation day***: DK

on																								
off																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Q30. Draw a line that describes the fan system operation for a ***light operation day***. DK

on																								
off																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Q31. Draw a line that describes the fan system operation for a ***closed operation day***. DK

on																								
off																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Q32. Is the fan system described above controlled by the building EMS? Y N DK

Q33. Is the fan system described above controlled using an optimum start algorithm? Y N DK

Note: For fans with optimal start/stop, indicate the building occupancy schedule - e.g. the time when the building needs to be at normal operating temperature.

Q34. List the nighttime (off cycle) control strategy for the fan system described above:

- ❑ Stay off regardless of room temperature
- ❑ Cycle on if any room requires heating or cooling
- ❑ DK

List the selected packaged HVAC systems that run on this schedule below:

HVAC Design and Control

The following questions will help us to understand how the HVAC systems operate in the building. (These questions are designed to be answered by someone familiar with the operation of the building mechanical and control systems.)

Q35. Does the building have a central energy management system (EMS)? Y N DK

In each question below, indicate if the control action specified is initiated by the central EMS.

Q36. What is the minimum cooling supply air temperature setpoint _____°F DK

Q37. How is the supply air temperature controlled? ❑ EMS?

- ❑ Fixed
- ❑ Reset based on outside air temp
- ❑ Reset based on zone temp
- ❑ DK

Q38. Are CO_2 sensors used to control outdoor air quantities? Y N DK ❑ EMS?

Shades and Blinds

Q39. If there are shades or blinds on windows, which ***best*** describes their general use?

- ❑ Always open
- ❑ Always closed
- ❑ Operated by occupants to control comfort
- ❑ Open when space is occupied, closed otherwise

Swimming Pools (only if indoors and served by system studied)

Q40. If the building has a heated swimming pool, what water temperature is maintained? _____°F DK

Q41. If the building has a heated swimming pool, is a pool cover used? Y N DK

Q42. If a cover is used, at what time is it normally put on the pool? _____ (military time, blank if DK)

Q43. If a cover is used, at what time is it normally removed from the pool? _____ (military time)

Spas (only if indoors and served by system studied)

Q44. If the building has a spa, what water temperature is maintained? _____°F DK

Q45. If the building has a spa, is a cover used? Y N DK

Q46. If a cover is used, at what time is it normally put on the spa? _____ (military time, blank if DK)

Q47. If a cover is used, at what time is it normally removed from the spa? _____ (military time)

Packaged HVAC Systems

	AC-	AC-	AC-	AC-
Equipment Name				
Location				
Manufacturer				
Model No (outdoor)				
Model No (indoor)				
Serial Number				
Cooling Cap (ton)				
Cooling Efficiency	EER SEER	EER SEER	EER SEER	EER SEER
Heating Fuel	Elec / Other	Elec / Other	Elec / Other	Elec / Other
Heating Capacity (kBtuh))				
Heating Efficiency)	COP HSPF AFUE	COP HSPF AFUE	COP HSPF AFUE	COP HSPF AFUE
Supply CFM				
Supply fan hp				
Sup fan mtr effic				
Sup fan control	Const / Cycles ❑ EMS	Const / Cycles ❑ EMS	Const / Cycles ❑ EMS	Const / Cycles ❑ EMS
Ret/Rel fan hp				
Rel fan mtr effic				
OA Control	Fix/Tmp/Enth ❑ EMS	Fix/Tmp/Enth ❑ EMS	Fix/Tmp/Enth ❑ EMS	Fix/Tmp/Enth ❑ EMS
Min OA Fraction				
Tstat Make/Mod				
Tstat Location				

Note: heating capacity for heat pumps is for compressor only; circle COP or HSPF for heat pumps, AFUE for gas heat

Note variance from plans and as-built; rooftop heat sources, curb leakage, accessibility, unusual tstat mounting or location.

Ducts Outside Conditioned Space

System	Type	Location	Dia or L x W (in)	Lineal Ft	Construction	R-Value	Notes
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		
	❑ Supply ❑ Return	❑ Plenum ❑ Outside ❑ Uncond.			❑ Sheet Metal ❑ Flex ❑ Fiberglass ❑ Duct Board		

Note variance from plans and as-built

Zone _____

Name _____ Zone Multiplier _____

Exterior Walls

Assembly Name	**Type Code**	Insul or U-value	R	HC	**Orientation** (N, NE, E, ,NW)	**H (ft)**	**W (ft)**
			R U				
			R U				
			R U				
			R U				
			R U				
			R U				
			R U				
			R U				
			R U				

Height and width are gross dimensions, including windows
Enter "0" for R-value if uninsulated, leave blank if unknown

	Wall Construction Type
1	Face Brick + Brick
2	Face Brick + Poured Concrete
3	Face Brick + Concrete Block

	Wall Construction Type
4	Poured Concrete + Finish
5	Concrete Block + Finish
6	Wood Frame Wall

	Wall Construction Type
7	Metal Frame Wall
8	Curtain Wall
9	Open

Roof

Assembly Name	**Type Code**	**Surf Code**	**Surf Color**	**Ceil Insul**	**Roof Insul**	**L (ft)**	**W (ft)**	Tilt (deg)	Orient (deg)	Plen H (ft)	Plen Wall R	Ret Air
				R U	R U							❑
												❑
												❑
												❑

Height and width are gross dimensions, including skylights
Enter "0" for R-value if uninsulated, leave blank if unknown
Tit = 0 for horizontal, Orient = 0 for North

	Roof Type
10	Concrete Deck Roof.
11	Wood Frame Roof
12	Metal Frame Roof

	Roof Surface		
1	Paint	4	Metal roofing
2	Elastomeric coating	5	Asphalt shingles or roll
3	Single ply membrane	6	Gravel (ballast)

	Color				
1	White	4	Grey	7	Med Brn
2	Silver	5	Green	8	Dk Brn
3	Lt grey	6	Lt Brn	9	Black

Zone _____ (contd)

Window/Skylight Types

Ref. No.	Assembly Name	**No. Panes**	**Glazing Type**	**Frame Type**	**Features (circle)**	**Meas.Trans.**	SHGC	U- value
1					Low e / gas fill			
2					Low e / gas fill			
3					Low e / gas fill			
4					Low e / gas fill			
5					Low e / gas fill			
6					Low e / gas fill			
7					Low e / gas fill			
8					Low e / gas fill			
9					Low e / gas fill			
10					Low e / gas fill			

	Glass Type
1	Clear
2	Tinted
3	Reflective
4	Fritted (diffusing)

	Plastic Type
5	Clear Plastic
6	Tinted Plastic
7	White Plastic
8	Translucent

	Window Frame Type
1	Standard Metal Frame
2	Thermally Broken Frame
3	Wood/Vinyl Frame

	Skylight Frame Type
4	Standard Metal Frame w/ Curb
5	Thermally Broken Frame w/ Curb
6	Standard Metal Frame w/o Curb
7	Thermally Broken Frame w/o Curb

Window/Skylight Geometry

Ref No.	**Tilt**	**Orient**	**H (ft)**	**W (ft)**	**Qty**	Int. Shade Type	Otr Ex Shd%	OH Offset	OH Proj	Side Fin Ofst	Side Fin Proj	**Skylite Shape**	**Oper?**
													Y/ N
													Y/ N
													Y/ N
													Y/ N
													Y/ N
													Y/ N
													Y/ N
													Y/ N
													Y/ N
													Y/ N
													Y/ N

Tit = 0 for horizontal, Orient = 0 for North. Tilt applies only to skylights. Side fins apply only to windows.
Otr Ex Shd% refers to exterior shading from adjacent buildings, building self-shading, thick vegetation, hillsides etc.
Interior Shade Type: 1 = Blinds; 2 = Light Shades or Drapes; 3 = Dark Shades or Drapes
Skylight Shape: 1 = Domed; 2= Flat; 3= Pyramid; 4= Ridge; 5= Vault

Space _____

Name ___________________ Floor Area_________SF

Corridor/Restroom/Support Area______% Space Multiplier______

Maximum Number of People___________

Circle appropriate occupancy code:

1 Auditorium
2 Church /chapel
3 Convention, meeting
4 Courtroom
5 Exhibit
6 Main entry lobby
7 Motion picture theater
8 Performance theater
9 Bars, lounge, casino
10 Dining
11 Kitchen
12 Bank/financial institution
13 Medical / clinical office
14 Office - Other
15 Computer center
16 EEG/EKG/MRI/Radiation
17 Hospital - Emergency
18 Hospital general area
19 Hospital laboratory
20 Hosp.patient rm/ nursery
21 Hosp. therapy (OT, PT)
22 Hospital Pharmacy
23 Hospital Radiology
24 Hospital Recovery
25 Hosp. Surgical & OB suite
26 Hotel function
27 Hotel guest room
28 Hotel lobby
29 Barber, beauty shop
30 Bowling alley
31 Coin op laundry
32 Comm'l dry cleaners
33 Grocery
34 Mall, arcade, atrium
35 Retail, whlse sales flr
36 Classroom
37 Day care
38 Dormitory
39 Gymnasium
40 Library
41 Locker room
42 School shop
43 Swimming pool
44 Aircraft hanger
45 Auto repair workshop
46 General C&I work, high bay
47 Precision C&I work
48 Storage, warehouse
49 Other (Describe)
50 General C&I, low bay (<25 ft)

Note: Codes 16 – 25 are for hospitals only

Lighting

Name	**Fixture Code**	**Fixture Count**	**Mount. Type**	**Track Length**	**Controls** (circle all that apply)		**% fix ctrl**	**% ctrl oper**
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		
					1 / 2 / 3 / 4	❏ EMS?		

Lighting Control Codes
1 = Occupancy sensor 2 = Daylight - contin. dimming 3 = Daylighting - stepped 4 = Lumen maintenance

Fixture Mounting Type Codes
1 = Rec 2 = Dir 3 = Ind 4 = Ind-Dir 5 = Plug-in Task 6 = Furn. Int. Task. 7 = Track 8 = Exempt

Space _____ contd

Miscellaneous Equipment and Plug Loads

Name	**Equip. Code**	**Count**	**Usage Factor**	kW/ Unit or	Motor HP or	kBtuh Input	Under Hood?
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N
							Y / N

Usage factor: Fraction of time equipment in use (0.0 – 1.0) to account for seldomly used equipment. Default is 1.0

Equipment - Record kW for equipment without default or if default is not appropriate

	Equipment Description	Equip Code	Default kW
General	Personal Computer w/ Monitor	1	0.5
	Terminal	2	0.15
	Laser Printer	3	0.85
	Small Copier	4	
	Medium Copier	5	
	Large Copier	6	
	Fax Machine	7	0.1
	Mini-Computer + Periph	8	1.0
	Main Frame Computer + Periph	9	
	Microwave	10	1.7
	Misc. Appliance	11	
	Television	12	0.15
	Washer	13	0.5
	Dryer	14	4.
	Cash Register	15	0.15
	Box Crusher	16	10.
	Gasoline pump	17	0.7
	ATM	18	.5
	Video game	19	.5
	Exercise equipment	20	.5

	Equipment Description	Equip Code	Default kW
Grocery	Meat Grinder	21	7.
	Meat Saw	22	2.5
	Meat Slicer	23	0.25
	Wrapper	24	0.9
	Check stand	25	1.5
Hospital	Laboratory Equipment	26	
	Monitoring, Life Support	27	1.1
	EEG	30	1.1
	EKG	31	1.1
	MRI	32	26.
	X-ray machine	33	5.
	Radiation Therapy Machine	34	10.
Indust	Air Compressor	35	
	Welder	36	
	Battery Charger	37	1.5
	Machine Tools	38	
	Motor	39	
Misc.	Other	40	

Refrigerated Cases

Zone: _____

Name	**Type**	**Qty**	**Unit Dim. (ft, CF)**	**Walk-in SF**	**Product**	**Comp Loc**	Door type (Reach-in)
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	
						Int / Rem	

Enter SF for walk-in or walk-in/reach-in only

Type Code	Case Description	Unit Dim.	Default kW/unit
1	Island, open, single-level narrow	ft	0.1
2	Island, open, single-level wide	ft	0.1
3	Island, open, island, single level double	ft	0.2
4	Island, closed, single-level narrow	ft	0.1
5	Island, closed, single-level wide	ft	0.1
6	Island, closed, single level double	ft	0.2
7	Open Single-deck	ft	0.3
8	Open Multi-deck	ft	0.3
9	Reach-in Multi deck	ft	0.3
10	Closed rear-entry multi-deck	ft	0.03
11	Curved glass rear entry multi deck	ft	0.06
12	Walk-in / Reach-in	ft	0.3
13	Walk-in	ft	0.015
14	Under counter Reach-in	CF	0.03
15	Blast Chiller	CF	0.03
16	Ice Maker	CF	0.04
17	Residential Reach-in Refrigerator	CF	0.03
18	Residential Reach-in Freezer	CF	0.03
19	Residential Closed Coffin Freezer	CF	0.03
20	Refrigerated Vending Machine	CF	0.03
21	Water cooler	each	0.5
22	Slurpee, frappaccino machine	each	
23	Other	kBtuh	

Product Code	Product
1	Ice Cream
2	Frozen Food
3	Fresh Meat
4	Deli
5	Dairy/Beverage
6	Produce

Door Code	Door Type
1	Single glazed
2	Double glazed
3	Triple glazed,
4	Quadruple glazed

Foodservice

Zone: _____

Kitchen Equipment

Appliance Name	Qty	Type	Fuel	KW *or*	Volts /	kBtuh	Trade Size	Hood
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N
			Elec. / Other		/			Y / N

Hoods

Name	Type	Size (SF)	Flow (cfm)	Fan hp	Makeup Air Source
	Canopy / Island Canopy / Backshelf				Cond / Uncond
	Canopy / Island Canopy / Backshelf				Cond / Uncond
	Canopy / Island Canopy / Backshelf				Cond / Uncond
	Canopy / Island Canopy / Backshelf				Cond / Uncond
	Canopy / Island Canopy / Backshelf				Cond / Uncond
	Canopy / Island Canopy / Backshelf				Cond / Uncond

Type Code	Description	Trade size	Default kW/unit
1	Broiler (include cheesemelter)	ft	1.7
2	Char Broiler	ft	3.7
3	Griddle, single sided	ft	4.5
4	Griddle, clam shell	ft	7.5
5	Fryer, countertop	lb	0.3
6	Fryer, free-standing	lb	0.3
7	Fryer, pressure	lb	0.3
8	Fryer, donut	lb	0.3
9	Kettle, Pasta cooker	qt	0.25
10	Heat lamps	lamps	0.5
11	Range top	ft	5.
12	Oven, pizza or bake	decks	7.
13	Oven, conveyor	decks	13.
14	Oven, range	ft	2.

Type Code	Description	Trade size	Default kW/unit
15	Oven, convection, combi, or retherm	doors	3.8
16	Food warmer	ft	0.6
17	Heated display case	ft	0.5
18	Microwave oven		1.7
19	Toaster, pop-up		1.8
20	Toaster, conveyor		4.6
21	Coffee pot	burners	1.
22	Steam table	ft	0.6
23	Dishwasher, single tank	racks/hr	0.3
24	Dishwasher, conveyor	racks/hr	0.1
25	Steam jacketed kettle	qt	0.4
26	Braising pan/skillet	qt	0.1
27	Other	kW	

Pools/ Spas

Name	Location	Surface Area (SF)
	Outside / Inside	
	Outside / Inside	
	Outside / Inside	
	Outside / Inside	

Incidents

Circle any incidents as applicable:

1 None to report
2 Complaint about rates
3 Complaint about energy costs or lack of savings
4 Complaint about outages or power quality
5 Complaint about technology reliability
6 Complaint about utility customer service
7 Contact person unavailable or unaware of survey appointment
8 Customer expressed dissatisfaction with survey (list reason(s))
9 Property damage occurred during on-site survey
10 Personal injury occurred during on-site survey
11 Other (list)

Designers

From the Mechanical plans, record the name, address and phone of the firm responsible for the mechanical design and Title 24 MECH compliance:

Mechanical Designer:

Name:

Address:

Phone:

Title 24 MECH compliance:

Name:

Address:

Phone:

System / Zone Association Checklist

DOE-2 "Virtual" System ----→	1	2	3	4
Packaged HVAC				
AC-1				
AC-2				
AC-3				
AC-4				
Zone 1				
Zone 2				
Zone 3				
Zone 4				

Interview "Area" / Audit "Zone" Association Checklist

Areas	1	2	3	4
Zone 1				
Zone 2				
Zone 3				
Zone 4				

Space/Zone Association

	Zone			
Space	Z 1	Z 2	Z 3	Z 4
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				

Sketch of Building Floor Plan

Be sure to include dimensions, North arrow, and zone and HVAC equipment locations

Employee Survey of Thermal Comfort

This is a short survey of your personal comfort while at work. Think about your comfort throughout the year. Does it change seasonally? How do you feel about your comfort? It should take you just a minute or two to complete the survey.

1) While at work, are you comfortable (from a temperature standpoint)?

- ❑ ***None of the time***
- ❑ ***Occasionally***
- ❑ ***About half of the time***
- ❑ ***Most of the time***
- ❑ ***All of the time***

2) If you are uncomfortable, is it: (check <u>any</u> that may apply)

- ❑ ***Too Hot***
- ❑ ***Too Cold***
- ❑ ***Too Drafty***
- ❑ ***Air Quality is poor (odors, dust, etc.)***

3) If you are uncomfortable, when does it occur? (check <u>all</u> that may apply)

❑ ***During the Winter***	❑ ***Too Hot***	❑ ***Too Cold***	❑ ***Drafty***
❑ ***During the Spring or Fall***	❑ ***Too Hot***	❑ ***Too Cold***	
	❑ ***Too Hot***	❑ ***Drafty***	
❑ ***During the Summer***	❑ ***Too Cold***	❑ ***Drafty***	

4) Does your work typically keep you at your desk/workstation:

- ❑ ***20% of the time or less***
- ❑ ***20-40% of the time***
- ❑ ***40-60% of the time***
- ❑ ***60-80% of the time***
- ❑ ***80 % or more of the work day***

5) My work area is: (check all that apply)

- ❑ ***In an area that is <u>further</u> than 15 feet from an outside wall of the building.***
- ❑ ***Within about 15 feet from a North wall of the building.***
- ❑ ***Within about 15 feet from a South wall of the building***
- ❑ ***Within about 15 feet from an East wall of the building***
- ❑ ***Within about 15 feet from a West wall of the building***

6) Please add any other comments regarding comfort to the back of this card. Thank You!!

Functional Performance Test

CARRIER Single-Package RTU

High Efficiency Electric Cooling/ Gas Heating

with Durablade or Economizer Dry-bulb Economizer

Model# 48HJD/HJE/HJF

1. Prerequisite Checklist

__ Onsite survey form complete
__ Power is present at all involved equipment

2. Economizer Model Verification

Note the economizer make and model number.

3. Functional Performance Testing

General Conditions of Test (date, time, ambient conditions, occupancy, etc.)

4. Preliminary Procedures

First test that the economizer damper actuator is operational
(this can only be performed on units with the Economi$er, not on Durablade units)

Procedure:

1. Locate the economizer controller
2. Make a note as to the current location of the minimum damper position adjuster
3. Slowly move the adjuster CW and CCW and verify that the damper moves accordingly. If the damper will not move, the unit fails the test and no further testing is necessary. If the damper moves with the adjuster, then proceed with the tests below. There may be a short delay before movement is witnessed.
4. Re-adjust the minimum damper position control to its original position.

Ready the thermostat interface for jumper testing and install the MDL sensors

Remove the wires from the connection board located in the RTU control panel that control the cooling and fan operation:

Note: the wires will either be connected between the “connection board” and a “relay pack module” or the “connection board” and the thermostat. Make notes below as to which wires were wired to which terminals.

Procedure:

1. Turn off RTU power via the main disconnect
2. Record existing thermostat wiring.
3. Remove and “wire-nut” the wire on terminal Y1
4. Remove and “wire-nut” the wire on terminal Y2
5. Remove and “wire-nut” the wire on terminal G
6. Install the supply, return and mixed air temperature MDL sensors, as well as the current measurement
7. Turn the power back on via the main disconnect

1) Normal Control Without Economizer

Adjust the OA temperature setting such that it is below the current OAT (or apply heat to the OA sensor), and jumper R to G and R to Y1 so that there is a call for cooling stage 1 and fan operation.

Expected Response: SF runs, economizer moves to minimum damper position, compressor 1 turns on, heat is off. Barometric relief damper should be closed.

2) Normal Control With Economizer Active

Adjust the OA temperature setting such that it is above the current OAT (use cold “tech” spray on the OA sensor if necessary), and jumper R to G and R to Y1 so that there is a call for cooling stage 1 and fan operation.

Expected Response: SF runs, economizer modulates open to meet the discharge air temp setting of approximately 55F. Compressor 1 is off, heat is off. Barometric relief dampers open with increasing OA flow. (If supply air is above 57F, OA damper opens. If supply air is between 57F and 52F, damper stays in current position. If supply air is below 52F, damper closes to minimum position)

- Return the economizer enable setpoint to 71F (OA temperature setting), and re-install the thermostat wires

Functional Performance Test

Standard Single-Package RTU

High Efficiency Electric Cooling/ Gas Heating

with Honeywell Economizer

1. Prerequisite Checklist

__ Onsite survey form complete
__ Power is present at all involved equipment

2. Economizer Model Verification

Note: Enthalpy only will only have one enthalpy sensor for the outside air condition. Differential enthalpy will have outside air and return air measurements.

If on the W7459 economizer controller there are:

- wires on terminals 'SO' and '+", then an outside air enthalpy sensor is present.
- wires on terminals 'SR' and '+", then a return air enthalpy sensor is present.
- wires on terminals 'SO' and '+", and a jumper on terminals 'SR' and '+", then your system is a single point outside air enthalpy economizer
- If both 'SO' and 'SR' have sensors attached, then it is a differential enthalpy economizer

If an outside air enthalpy sensor is used, the model number should be C7400.

If an outside air temperature sensor is used, the model number is C7650A.

3. Functional Performance Testing

General Conditions of Test (date, time, ambient conditions, occupancy, etc.)

4. Preliminary Procedures

<u>First test that the economizer damper actuator is operational</u>

Procedure:

1. Locate the economizer controller
2. Make a note as to the current location of the minimum damper position adjuster
3. Slowly move the adjuster CW and CCW and verify that the damper moves accordingly. If the damper will not move, the unit fails the test and no further testing is necessary. If the damper moves with the adjuster, then proceed with the tests below. There may be a short delay before movement is witnessed.
4. Re-adjust the minimum damper position control to its original position.

Ready the thermostat interface for jumper testing and install the MDL sensors

Remove the wires from the connection board located in the RTU control panel that control the cooling and fan operation:

Note: the wires will likely be connected to the thermostat.

Procedure:

1. Turn off RTU power via the main disconnect
2. Record existing thermostat wiring.
3. Remove and "wire-nut" the wire on terminal Y1
4. Remove and "wire-nut" the wire on terminal Y2
5. Remove and "wire-nut" the wire on terminal G
6. Install the supply, return and mixed air temperature MDL sensors, as well as the current measurement
7. Turn the power back on via the main disconnect

1) Normal Control Without Economizer

Change the enthalpy setting on the controller to 'D' for testing purposes.

Either warm-up or spray moisture near the OA enthalpy sensor (use a hot damp rag on the OA sensor if necessary) such that the enthalpy is above the lockout setpoint (or above the return air enthalpy sensor if present), and jumper R to G and R to Y1 so that there is a call for cooling stage 1 and fan operation.

Expected Response: SF runs, economizer moves to minimum damper position, compressor 1 turns on, heat is off. Barometric relief damper should be closed.

Note: The LED on the economizer controller lights when the OA is suitable for free cooling – during this test, the LED should be off.

2) Normal Control With Economizer Active

Change the enthalpy setting on the controller to 'A' for testing purposes. Be sure to return it to its original position when the tests are completed.

Cool down the OA enthalpy sensor (use cold "tech" spray near the OA sensor in the airstream if necessary) such that the enthalpy is below the lockout setpoint (or below the return air enthalpy sensor if present), and jumper R to G and R to Y1 so that there is a call for cooling stage 1 and fan operation.

Expected Response: SF runs, economizer modulates open to meet the discharge air temp setting of approximately 55F. Compressor 1 is off, heat is off. Barometric relief dampers open with increasing OA flow.

Note: The LED on the economizer controller lights when the OA is suitable for free cooling. If the LED does not illuminate properly, make note of this in your records.

- Return the economizer enable setpoint to its original setting, and re-install the thermostat wires

Functional Performance Test

TRANE Single-Package RTU

High Efficiency Electric Cooling/ Gas Heating

with Economizer

Model# YCD/YCH

1. Prerequisite Checklist

__ Onsite survey form complete
__ Power is present at all involved equipment

2. Economizer Model Verification

Locate the economizer controller "Unit Economizer Module" (UEM) – remove the fresh air adjustment panel located on the unit end panel to access the UEM. In the bottom left corner are terminals labeled J7,J8,J9,J10. If there are wires on any of these terminals then likely there is an enthalpy control instead of dry-bulb control present.

Note the economizer make and model number.

If on the UEM economizer controller there are:

- wires on terminals 'J7' and 'J8', then a return air enthalpy sensor is present.
- wires on terminals 'J9' and 'J10', then an outside air enthalpy sensor is present.
- If only outside air enthalpy sensor is present, then your system is a single point enthalpy economizer
- If both air enthalpy sensors are present, then your system is a differential enthalpy economizer
- If neither return or outside air enthalpy/humidity sensors are present, then it is a temperature only economizer. The OA sensor is located near the condenser and is a small metal probe.

If an outside air enthalpy sensor is used, the model number should be C7600A. (it is actually a humidity sensor, because the TRANE unit measure outside air temperature from a different control module, located on the control board 'UCP', terminals J1-15 and J1-16)

3. Functional Performance Testing

General Conditions of Test (date, time, ambient conditions, occupancy, etc.)

4. Preliminary Procedures

First test that the system controls are operational

Procedure:

1. Locate the Low Voltage Terminal Strip (LTB)
2. To begin the *Step Test Mode*, place a jumper across "TEST1" and "TEST2" terminals for 2 to 3 seconds, then remove them.
3. When the test mode is initiated, the light on the Unitary Control Processor (UCP) will blink and the system will begin the first test step, and turn on the fan (see table below).
4. To continue to the economizer step, reapply the jumper to the test terminals for 2 to 3 seconds. Pay special attention to *step 2* to witness if the economizer damper opens during this test.

Test Mode Table

Step	Mode	Fan	Econ	C1	C2	Heat 1	Heat 2	Heat 3	Defrost	Em Heat
1	Fan On	On	Min	Off	Off	Off	Off	Off	Off	Off
2 *	Econ.	On	Open	Off	Off	Off	Off	Off	Off	Off
3	Cool 1	On	Min	On	Off	Off	Off	Off	Off	Off
4	Cool 2	On	Min	On	On	Off	Off	Off	Off	Off
5	Heat 1	On	Min	Off	Off	On	Off	Off	Off	Off
6 *	Heat 2	On	Min	Off	Off	Off	On	Off	Off	Off
7 *	Heat 3	Not Applicable on Gas/Electric Units.								
8 **	Defrost	Not Applicable on Gas/Electric Units.								
9 **	Em Heat	Not Applicable on Gas/Electric Units.								

* With Optional Accessory ** With Heat Pump

Note: Steps for optional accessories and modes not present in unit, will be skipped.

5. To terminate the test mode, continue stepping through the modes until the UCP indicator light glows constantly. At the end of the test mode, the indicator light will glow constantly and control will revert to the zone sensor.

Test that the economizer damper actuator is operational

Procedure:

1. Locate the economizer controller "Unit Economizer Module" (UEM) – remove the fresh air adjustment panel located on the unit end panel to access the UEM
2. Locate the "Minimum Damper Position" adjustment pot on the UEM. Make a note as to the current location of the minimum damper position adjuster
3. Note the approximate minimum damper position as percent open to outside air .
4. Slowly move the adjuster CW and CCW and verify that the damper moves accordingly. Fully CCW = 0% outside air, Fully CW = 50% outside air. If the damper will not move, the unit fails the test and no further testing is necessary. If the damper moves with the adjuster, then proceed with the tests below. There may be a short delay before movement is witnessed.
5. Note the existing "SW1" and "SW2" switch setting on the UEM board (if the switch is towards the center of the UEM board, it is in the ON state)
6. Re-adjust the minimum damper position control to its original position.

Install the MDL sensors

Procedure:

1. Turn off RTU power via the main disconnect
2. Install the supply, return and mixed air temperature MDL sensors, as well as the current measurement
3. Turn the power back on via the main disconnect

The following tests require 2 people with communication radios to efficiently perform. If this is feasible, then continue with the tests. One person will need to be at the unit, and another at the thermostat.

1) Normal Control Without Economizer

Adjust the OA economizer setting such that it is below the current OAT (moving SW1 to OFF, and SW2 to ON will result in a 55°F OA temperature setting), and adjust the thermostat down so there is a call for cooling stage 1 and fan operation

Expected Response: SF runs, economizer moves to minimum damper position, compressor 1 turns on, heat is off. Barometric relief damper should be closed.

2) Normal Control With Economizer Active

Adjust the OA temperature setting such that it is above the current OAT (use cold "tech" spray on the OA sensor if necessary), and adjust the thermostat down so there is a call for cooling stage 1 and fan operation (same as test#1 setting).

Note: Moving SW1 to ON, and SW2 to OFF will result in a 65°F OA temperature setting (and high enthalpy requirement), and/or use cold "tech" spray on the OA sensor if necessary.

Expected Response: SF runs, economizer modulates open to meet the discharge air temp setting of between 50F and 55F. Compressor 1 is off, heat is off. Barometric relief dampers open with increasing OA flow.

- Return the economizer enable switches (SW1 & SW2) to their original settings as noted on this page.

Functional Performance Test

Standard Single-Package RTU

High Efficiency Electric Cooling/ Gas Heating

with Dry-bulb Economizer

1. Prerequisite Checklist

__ Onsite survey form complete
__ Power is present at all involved equipment

2. Economizer Model Verification

Note the economizer make and model number.

3. Functional Performance Testing

General Conditions of Test (date, time, ambient conditions, occupancy, etc.)

4. Preliminary Procedures

First test that the economizer damper actuator is operational

Procedure:

1. Locate the economizer controller
2. Make a note as to the current location of the minimum damper position adjuster
3. Slowly move the adjuster CW and CCW and verify that the damper moves accordingly. If the damper will not move, the unit fails the test and no further testing is necessary. If the damper moves with the adjuster, then proceed with the tests below. There may be a short delay before movement is witnessed.
4. Re-adjust the minimum damper position control to its original position.

Ready the thermostat interface for jumper testing and install the MDL sensors

Remove the wires from the connection board located in the RTU control panel that control the cooling and fan operation:

Note: the wires will likely be connected to the thermostat.

Procedure:

1. Turn off RTU power via the main disconnect

2. Record existing thermostat wiring.

3. Remove and “wire-nut” the wire on terminal Y1
4. Remove and “wire-nut” the wire on terminal Y2
5. Remove and “wire-nut” the wire on terminal G
6. Install the supply, return and mixed air temperature MDL sensors, as well as the current measurement
7. Turn the power back on via the main disconnect

1) Normal Control Without Economizer

Adjust the OA temperature setting such that it is below the current OAT (or apply heat to the OA sensor), and jumper R to G and R to Y1 so that there is a call for cooling stage 1 and fan operation.

Expected Response: SF runs, economizer moves to minimum damper position, compressor 1 turns on, heat is off. Barometric relief damper should be closed.

2) Normal Control With Economizer Active

Adjust the OA temperature setting such that it is above the current OAT (use cold “tech” spray on the OA sensor if necessary), and jumper R to G and R to Y1 so that there is a call for cooling stage 1 and fan operation.

Expected Response: SF runs, economizer modulates open to meet the discharge air temp setting of approximately 55F. Compressor 1 is off, heat is off. Barometric relief dampers open with increasing OA flow.

- Return the economizer enable setpoint to 71F (OA temperature setting), and re-install the thermostat wires

Functional Performance Test

Standard Single-Package RTU

High Efficiency Electric Cooling/ Gas Heating

with Enthalpy Economizer

1. Prerequisite Checklist

__ Onsite survey form complete
__ Power is present at all involved equipment

2. Economizer Model Verification

Note: Enthalpy only will only have one enthalpy sensor for the outside air condition. Differential enthalpy will have outside air and return air measurements.

3. Functional Performance Testing

General Conditions of Test (date, time, ambient conditions, occupancy, etc.)

4. Preliminary Procedures

First test that the economizer damper actuator is operational

Procedure:

1. Locate the economizer controller
2. Make a note as to the current location of the minimum damper position adjuster
3. Slowly move the adjuster CW and CCW and verify that the damper moves accordingly. If the damper will not move, the unit fails the test and no further testing is necessary. If the damper moves with the adjuster, then proceed with the tests below. There may be a short delay before movement is witnessed.
4. Re-adjust the minimum damper position control to its original position.

Ready the thermostat interface for jumper testing and install the MDL sensors

Remove the wires from the connection board located in the RTU control panel that control the cooling and fan operation:

Note: the wires will likely be connected to the thermostat.

Procedure:

1. Turn off RTU power via the main disconnect
2. Record existing thermostat wiring.
3. Remove and “wire-nut” the wire on terminal Y1
4. Remove and “wire-nut” the wire on terminal Y2
5. Remove and “wire-nut” the wire on terminal G
6. Install the supply, return and mixed air temperature MDL sensors, as well as the current measurement

7. Turn the power back on via the main disconnect

1) Normal Control Without Economizer

Either warm-up or spray moisture near the OA enthalpy sensor (use a hot damp rag on the OA sensor if necessary) such that the enthalpy is above the lockout setpoint (or above the return air enthalpy sensor if present), and jumper R to G and R to Y1 so that there is a call for cooling stage 1 and fan operation.

Expected Response: SF runs, economizer moves to minimum damper position, compressor 1 turns on, heat is off. Barometric relief damper should be closed.

2) Normal Control With Economizer Active

Cool down the OA enthalpy sensor (use cold "tech" spray near the OA sensor if necessary) such that the enthalpy is below the lockout setpoint (or below the return air enthalpy sensor if present), and jumper R to G and R to Y1 so that there is a call for cooling stage 1 and fan operation.

Expected Response: SF runs, economizer modulates open to meet the discharge air temp setting of approximately 55F. Compressor 1 is off, heat is off. Barometric relief dampers open with increasing OA flow.

- Return the economizer enable setpoint to its original setting, and re-install the thermostat wires

Power Measurements
October 11, 2001

Spot power measurements for 3-phase delta connected loads (Nearly all 3-phase motors fit this category):

There are two techniques described here. For consistency, use the ***phase to neutral method*** unless the ground is not reliable. Using the Phase-to-neutral method gives you a direct indication of power factor. Use the Phase-to-phase method only if a good neutral or ground connection cannot be established.

Phase-to-neutral method:
Technically, there isn't a neutral available to perform this technique. However, the ground can often be substituted if there's a good connection between ground and the neutral in the building.

Three power measurements are required.

Here's the step-by-step procedure when using a single-phase power meter (All our fluke power meters are single-phase meters):

1. Connect the black voltage lead to Neutral (or ground)
2. Connect the red voltage lead to Phase A
3. Connect the current clamp to Phase A, being sure to verify that the clamp is facing the right direction. Click the *phase check* button on the fluke to verify proper connection.
4. Read and record the power voltage, current, and power factor measurement
5. Move the voltage lead and current clamp to Phase B and repeat step 4.
6. Move the voltage lead and current clamp to Phase C and repeat step 4.
7. Disconnect the voltage leads

Phase-to-phase method:
Only two power measurements are required.

Here's the step-by-step procedure when using a single-phase power meter (All our fluke power meters are single-phase meters):

1. Connect the black voltage lead to Phase B
2. Connect the red voltage lead to Phase A
3. Connect the current clamp to Phase A, being sure to verify that the clamp is facing the right direction. Click the *phase check* button on the fluke to verify proper connection.
4. Read and record the power measurement
5. Read and record the current measurement for Phase A
6. Read and record the voltage measurement for Phase A-B

7. Move the red voltage lead from Phase A to Phase C. Leave the black voltage lead on Phase B.
8. Move the current clamp to Phase C, being sure to verify that the clamp is facing the right direction. Click the *phase check* button on the fluke to verify proper connection.
9. Read and record the power measurement
10. Read and record the current measurement for Phase C
11. Read and record the voltage measurement for Phase C-B
12. Move the current clamp to Phase B
13. Read and record the current measurement for Phase B.
14. Disconnect the voltage leads

Methods for measuring power on single-phase loads connected phase-to-phase (many condenser and supply fans fall in this category):

This can be accomplished in two ways. Either technique can be used. Regardless of the technique used, NOTE ON THE FORM that this is a single-phase load operating phase-to-phase.

Use the *phase-to-neutral method*, described above. Since there are only two connections to the load, only two power measurements are required.

Use the *phase-to-phase method*, described above, using the unused phase as the reference. It may or may not be Phase B.

The following technique **does not** work, although intuitively it seems like it should work properly. Don't use it:
Take a single measurement of current, voltage, power factor, and power with the voltage leads connected to the phases serving the load. This method does not provide a good measurement of power factor.

NBI SMALL HVAC ECONOMIZER TEST DATA

Site ID# _____ Date _____

Building Name _____ General outside air conditions _____

Participants _____

_____

RTU Name/ number				
RTU Manufacturer				
Economizer Present? (Y/N)				
Economizer Make and Model#				
Economizer setpoint setting (A,B,C,D or switches SW1, SW2)				
Minimum OA damper position (%)				
Record the minimim damper position adjuster setting	○	○	○	○
Does the actuator move, and the linkage operate? (Y/N)				
Economizer type: (check one) *single point temperature* *differential temperature* *single point enthalpy* *differential enthalpy*				
Thermostat Wire Colors: *R - power* *G - Fan* *Y1 - Cool stage 1* *Y2 - Cool stage 2*				
Are there jumpers between the thermostat wire? Note which wires.				
Does the economizer respond to cold air on the sensor? (Y/N)				